BOURNEMOUTH UNIVERSITY

A SAFETY TRANSPORT FRAMEWORK FOR HIRED COACHES FOR SCHOOL TRANSPORT

Manoharan Ramachandran

HDSE, B.Tech., M.E.

Doctor of Philosophy

2019

Bournemouth University

A SAFETY TRANSPORT FRAMEWORK FOR HIRED COACHES FOR SCHOOL TRANSPORT

PhD Thesis

Manoharan Ramachandran

HDSE, B.Tech., M.E.

A thesis submitted in partial fulfilment of the requirements for the degree of Doctor of Philosophy

March 2019

Copyright

Abstract

Safety in school transport is a critical issue which involves children who are the most vulnerable users of it. On an average 973 trips are made per person in a year, out of which 105 are on school runs. In the United Kingdom (UK) alone, 1218 children were injured in 381 coach crashes between 2005 and 2016. Driver errors or technical faults in vehicles were the most commonly reported contributory factors for coach accidents. Coaches are considered as the safest mode of transport for children, but coach accidents result in a high number of fatalities per accident as coaches carry more children compared to any other means of school transport. There are more than 24000 schools in England alone and each school makes at least two field trips per year, which is equivalent to 48000+ trips. Schools in the UK rely on coach operators to provide vehicles for short and long school trips. In the UK there are strict regulations on operator's compliance with the government safety regulations. In last year alone, 78 coach operators' licenses have been revoked without public inquiries in the UK due to operator's non-compliance. Though the government has strict safety regulations, accidents are still happening. Most of the existing literature has focused on economical and shortest routes to transport children, but they do not consider the safety aspects of the coach operators, coaches and the drivers in terms of compliance with the government safety regulations. Proper selection of coach operator, coach and driver can considerably mitigate safety risks for school transport. Only limited studies have examined safety of children travelling by coaches in the UK.

This research involves a thorough analysis of the existing literature, national accident statistics, government policies, and traffic commissioner's report. Two surveys were conducted with stakeholders (parents, school headmasters, coach operators, coach drivers, council transport officers and road safety analysts) to identify safety-related issues and the requirements of stakeholders in coach-based school transport in the UK. The analysis of the outcome shows that there are significant safety issues exist and there is a requirement for a safety transport framework to support users of hired private coaches in the UK to transport schoolchildren. A novel safety transport framework for hired coaches is proposed to address the identified safety issues. The framework validates coach operators, their coaches and drives using safety scores, based on their track record. This information can be shared with the school headmasters and parents before booking coaches. The framework also provides recommendations to coach operators to improve their fleet safety. The framework is prototyped, and both the framework and the prototype were evaluated within the UK. The evaluation shows that the framework has achieved its intended objectives and received positive feedback from the stakeholders.

Dedicated to my Parents and my Sister for their unconditional love and support…

என் பெற்றோர் மற்றும் என் தங்கைக்கு இந்த ஆய்வுக்கட்டுரை சமர்ப்பணம்...

Acknowledgements

I would like to thank a number of people who have all aided me in some way or the other during the past 36 months that were both enjoyable and challenging.

Firstly, I would like to thank my loving parents, D.E. Ramachandran and R.Gnanasowndari and my sister, R.Divya for always believing in me and motivating me to always aim high and work hard; and they are the people behind my every achievement.

I would like to extend my sincere gratitude to my supervisors, Professor Reza Sahandi, Dr Simant Prakoonwit and Dr Wajid Khan for not only mentoring me but also inspiring me to stay focused on my goal always. I am very thankful to them for their invaluable guidance and extreme patience throughout my research.

I would like to specially thank Professor Reza Sahandi who closely mentored me from the beginning and helped me to recover from my down times. I always felt motivated after our supervisory meetings. Without his help I would not have been stayed motivated till the end of this PhD.

I would like to thank the managing directors of County Coaches, Mr James Gardner and Ms Rose Carville, for their constant support and motivation from the industrial side.

I would also like to thank Bournemouth University and County Coaches for funding this research so as to manage my research expenses.

I would also like to thank all the participants who, by being a part of the interviews, contributed to a major part of my research.

Lastly, I want to thank everyone who helped me in the various stages of my research in order to complete my research successfully.

Contents

List of Figures

List of Tables

List of Abbreviations

GB	Great Britain
BRG	Bus Route Generation
BSS	Bus Stop Selection
BV	Bus stops Visited
CCTV	Closed-Circuit TeleVision
COCRS	Combined Operator Compliance Risk Score
CTSAM	Coach Travel Safety Analysis Matrix
DBS	Disclosure and Barring Services
DfT	Department for Transport
DP	Data Preparation
DVLA	Driver and Vehicle Licensing Agency
DVSA	Driver and Vehicle Standard Agency
GPS	Global Positioning System
HARP	Heightening your Awareness of your Research Philosophy
HGV	Heavy Goods Vehicles
HM	Health Monitoring
HSS	Home to School Services
ISTS	Intelligent School Transportation Systems
IVA	In-Vehicle-Attendance
LB	Load Balancing
MOT	Ministry of Transport
OCH	Occasional Coach Hires
PD	Passenger Demand

PSV	Private Sector Vehicles
ROCRS	Roadworthiness Operator Compliance Risk Score
RFID	Radio Frequency Identification
RS	Route Scheduling
RT	Ride Time
SBRP	School Bus Routing Problem
SBTA	School Bell Time Adjustment
SLT	Student Location Tracking
SR	Students for a Route
STS	School Transportation Systems
TBD	Total Bus travel Distance
TC	Transportation Costs
TOCRS	Traffic Operator Compliance Risk Score
TRL	Transport Research Laboratory
TSD	Total Student riding Distance
TT	Terrain Type
TW	school Time Window
UK	United Kingdom
VC	Vehicle Capacity
VDBM	Vehicle-Driver Behaviour Monitoring
VLT	Vehicle Location Tracking
VOSA	Vehicle and Operator Service Agency
WD	Walking Distance
WT	Waiting Time

List of Publications

- Ramachandran, M., Sahandi, R., Prakoonwit, S., and Khan, W., 2016. "*Intelligent Safety Transport Framework for Schools: A Review of Route Planning and Tracking Systems"*, MATEC Web Conf. Vol 81, 2016, presented in 5th International conference on transportation and traffic engineering (ICTTE 2016), Lucerne, Switzerland 2016.
- Ramachandran, M., Sahandi, R., Prakoonwit, S., and Khan, W., *"A Safety Transport Model for Validation of UK Coach Operators for School Journeys"* International conference on Intelligent Transport Systems – From research and development to the market uptake, Helsinki November 2017.
- Ramachandran, M., Sahandi, R., Prakoonwit, S., and Khan, W., *"Mathematical Model for Safety Score Calculation for Validation of Coach Operators in the UK"* International conference on Intelligent Transport Systems – From research and development to the market uptake, Helsinki November 2017.
- Ramachandran, M., Sahandi, R., Prakoonwit, S., and Khan, W., *"Coach Travel Safety Analysis Matrix (CTSAM): A tool for analysing safety of children travelling by coaches in the UK"* IEEE International Conference On EECCMC, Vellore Feb 2018.
- Ramachandran, M., Sahandi, R., Prakoonwit, S., and Khan, W., *"An Intelligent Recommendation Model for Coach Operators"* IEEE International Conference On EECCMC, Vellore Feb 2018.
- Ramachandran, M., Sahandi, R., Prakoonwit, S., and Khan, W., *"Safety of Coach Based School Transport in the UK: A Study of Safety Compliance of Coach Operators and Trust of Stakeholders"* Submitted to IEEE IET International Journal.

Author's declaration

I declare that the work in this thesis was carried out in accordance with the regulation of Bournemouth University. The work contained in this thesis is the result of my own investigations and has not been accepted nor was concurrently submitted in candidature for any other award.

I declare that while registered as a candidate for the research degree, I have not been a registered candidate or enrolled student for another award of the university other academic or professional institution.

Signature of Candidate: Manoharan Ramachandran

Date: 2019

Type of Award: Doctor of Philosophy

School: Science and Technology

Chapter 1

Introduction

1.1 Background

Transport is an essential part of any society and its economy for its sustainable function. Safety in transport is concerned with the protection of life by regulating, managing and developing technology for all forms of transport. People use transport for day-to-day activities such as school, work and business movements or social and leisure purposes. An average of 973 trips is made per person in a year, out of which 105 are on school runs (Kalogirou et al. 2012). Safety in School Transport Systems (STS) is a critical issue, which involves children who are the most vulnerable users (The Scottish Government 2009, Kalogirou et al. 2012). Statistics show that in the United Kingdom (UK), which includes England, Scotland and Wales (Northern Ireland Excluded), 1218 children were injured in 381 coach crashes between 2005 and 2016, which is equivalent to on an average of 101 children getting injured every year (DfT 2017a). Driver errors and technical faults in vehicles are the most commonly reported factors contributing to coach accidents (DfT - Ras50005 2017). Although coach journeys are considered the safest mode of transport for children, coach accidents are the ones, which result in many fatalities per accident as coaches carry a large number of children compared to any other means of road transport (Albertsson et al. 2003, Doohan and Saveman 2014). England has more than 24,000 schools and each school at least makes two trips per year to field trips, sports matches, team events etc., which is equivalent to more than 48,000 local journeys made every year (Drake 2016). Schools rely on coach operators to provide vehicles for school trips and school/home services (Move 2016). In the UK, there are strict government regulations on operator's compliance. If operators are found with minor regulation violations, they will be sent to a Traffic Commissioners for further investigation. If they have committed major violations, then their license will be revoked without a public enquiry. Between 2016 and 2017 alone, 78 coach operators' licenses have been revoked without public inquiries in the UK due to major violations (Commissioners 2017).

Basically, school transport using coaches can be classified into two types, Home to School Services (HSS) and other activities which require Occasional Coach Hire (OCH) (field trips, sports matches, etc.). In respect of HSS, coach operators usually advertise the service and its routes. Parents, who find it suitable for their children, adopt the service. As it is a routine journey and the same route is taken most of the time, HSS are mostly safe. However, there are opportunities to improve safety in respect of OCH for students' field trips. These kinds of journeys usually involve high risks compared to home to school transport because of the length of the journeys (O'neal et al. 2014). Recent innovations in STS (Faraj et al. 2014, Huang et al. 2014, Silva et al. 2015), gave birth to Intelligent School Transport Systems (ISTS), which addressed some of the issues in STS (Falkmer et al. 2014, Harrison et al. 2014, Mammen et al. 2015) such as optimal routing of school vehicles, continuous monitoring of school coaches and children.

Coach accidents due to vehicle error and driver error are still happening even having strict safety regulations from the government and operator non-compliance with the safety regulations still exist. Only a limited number of researches have examined the safety aspects of coach operators, their vehicles and drivers in the UK (Van Ristell et al. 2014). Further, there is no specific safety model/framework available to ensure the safety of children travelling by coaches (Ramachandran et al. 2016). So, there is a need for an exploratory research on the safety of children in coach-based school transport. Based on the initial analysis, an intelligent safety system can improve the safety of coach transport carrying children in the UK (Ramachandran et al. 2016). To respond to the above issues, a number of research questions are formulated, as listed below.

1.2 Research Questions

1. Are hired coaches in the UK really a safe option for transporting school children?
2. What are the safety-related issues in coach-based school transport in terms of coach operations and compliance with the government regulations, which must be considered?
3. Do any frameworks exist to support the safety of school transport by verifying operator safety compliance? If so, are they capable of providing safety for school children travelling by hired coaches?
4. What are the limitations of the existing safety frameworks for coach-based school transport carrying children?
5. How to overcome the existing limitations through intelligent safety solutions?

1.3 Aim

To explore the safety level of coach-based school transport in the UK in-terms of coach operations and safety compliance and to provide the necessary safety solutions to improve the safety of school children travelling by hired coaches.

1.4 Objectives

1. To investigate existing literature, STATS19 accident database, current government safety standards and traffic commissioner reports for understanding the safety of current school transport by coaches in the UK.

2. To conduct a qualitative survey (semi-structured interviews) with the stakeholders (parents, school headmasters, coach operators, coach drivers, council transport officers and road safety analysts) of school transport and analyse the data gathered.
3. To identify safety-related issues and the requirements of stakeholders in coach-based school transport in terms of coach operations and safety compliance.
4. To conduct a quantitative survey across the UK to identify critical safety issues and requirements of stakeholders for schoolchildren transport.
5. To propose a safety transport framework to help schools and parents to choose fully compliant coach operators and also to provide safety recommendations to coach operators to improve their fleet safety.
6. To develop a prototype of the framework to illustrate proof of concept.
7. To evaluate the proposed framework and its prototype.

1.5 Contributions

1. ***Coach Travel Safety Analysis Matrix (CTSAM):*** A tool created to analyse the safety of coach-based school transport in the UK (Ramachandran et al. 2018a).
2. ***Safety transport framework:*** A unique safety transport framework, which can be used to validate coach operators, coaches and drivers at the time of booking a coach is proposed. The framework enables schools to select a safe operator. (Ramachandran, Sahandi, Prakoonwit, and Khan 2017, Ramachandran, Sahandi, Prakoonwit, Khan, et al. 2017).
3. ***Intelligent system for safety recommendation:*** An intelligent system that provides safety recommendations to coach operators that enables coach

operators to improve the safety of their fleets is proposed (Ramachandran et al. 2018b).

1.6 Thesis Organisation

This thesis has been divided into seven chapters. The chapters' contents are summarized below:

Chapter one: It discusses the background and the motivation for the research. Based on the literature review discussions, the primary research aim, research questions and objectives were developed. The research contributions and an outline of the research are provided. Overall, this chapter aims to justify and clarify the research problem that is being investigated in this PhD thesis.

Chapter two: Provides a detailed literature review on coach/bus-based school transport around the world and in the UK. Information about coach accidents involving school children extracted from STATS 19 database is included along with the common contributory factors for the coach accidents. This is followed by the analysis of government policies and guideline and a complete review of the related studies in these areas. This chapter concludes by highlighting the main issues present in the coach-based school transport and justifies the research objectives listed in chapter one.

Chapter three: Presents the details of the research methodology used in this study. The implementation of the sequential mixed-method exploratory research design (qualitative surveys followed by quantitative survey) and the consequent analysis of the data collected are presented in this chapter.

Chapter four: Provides the empirical findings of chapter three and discuss the survey results in detail. From the survey results, the significant issues and requirements of stakeholders are identified. The chapter concludes by presenting the final observations of the surveys and explains what needs to be done to resolve the significant issues and requirements identified by the survey.

Chapter five: This chapter discusses the development of a proposed safety transport framework. Five-steps are involved in the framework providing the theoretical underpinning of the framework. Further, the framework is expressed mathematically and tested with real data. The chapter concludes by presenting the results of testing of the framework.

Chapter six: This chapter discusses the prototyping of the framework and the evaluation of both the prototype and the framework. The evaluations were carried out through the involvement of stakeholders of coach-based school transport across the UK.

Chapter seven: This chapter concludes by highlighting the implications of this research and further identifies areas of future work.

1.7 Chapter Summary

Safety of school transport is a critical issue which should be addressed effectively. Safety in coach-based school transport in the UK is a less investigated area compared to other modes of school transport. This requires immediate attention before more children lives are put at risk. This chapter provided an introduction to the safety level of coach-based school transport in the UK, overarching research aim and objectives, thesis structure and finally, the novel contributions made thus far by this research work.

Chapter 2

Literature Review

2.1 Introduction

This chapter discusses the related research of the topics which are covered in this thesis. As the scope of this thesis is to explore the safety level of coach-based school transport in-terms of coach operations and safety compliance, the literature on the safety-related aspects of coach/bus-based school transport research was reviewed. We took the UK as our case study area for in-depth analysis of safety of children travelling by hired coaches. A concise analysis of coach accident statistics involving children, contributory factors for coach accidents, government policies & guidelines and traffic commissioner reports of the UK are presented. This chapter concludes by highlighting the main issues in the coach-based school transport and identifies a gap in knowledge through literature review.

2.2 School Transport

School transport is the process of carrying schoolchildren to and from school, as well as field trips. Children use various modes of transport to go to school. The mode of transport varies from country to country and depending on factors such as weather, road conditions, financial issues, convenience etc. (Stark et al. 2018). Children may go to school by walking, cycling or by using public transport. They may also travel by car if their family members wish to take them or they may use school transport (Hine and Preston 2017). The existing research has focused on different aspects of school transport which includes, active school transport (Villa-González et al. 2018), school travel behavior (Faulkner and Hinckson 2018), mode of choice to school (Assi et al. 2018), walking school buses (Pérez-Martín et al. 2018), school bus routing problems

(Miranda et al. 2018), school bus tracking (R et al. 2018) , school children tracking (Takalikar et al. 2018), safety frameworks for school travel (Country and Eu-funded 2015), emergency evacuation from school buses (Abulhassan et al. 2017), gender-based transport for commuting to school (Colley 2017), effect of travel mode on children studies (Westman et al. 2017), analysis of seatbelt usage in coaches (Beck and Nguyen 2017a) and school bus transport of children with special health care needs (Bull et al. 2018). Studies related to the aim and objectives of the thesis are explained in the following sections.

2.3 Related Studies

2.3.1 Holistic Studies

A recent European funded project conducted in Sweden "SAFEWAYTOSCHOOL" proposed a safety framework for children (Anund et al. 2010, 2011, Anund and Dukic 2011, Kalogirou et al. 2012, Falkmer et al. 2014). This project addresses most of the difficulties faced during school transport through a door to door approach (between home and school). At first, the safest routes are considered for children to reach the bus stop. When a child reaches the bus stop, an alert light is automatically turned on at the bus stop. When the bus reaches the bus stop to pick up the child, a warning sign on the bus is turned on to alert the people outside the bus. During the journey towards the school, children are notified to put their seatbelts on. In addition, audio-visual information is provided about the destination before reaching the school. Once the bus reaches the school stop, a notification light is turned on in the bus and the bus stop indicator light is also turned on. Finally, on arrival at the school, a notification message is sent to the parents. The study basically focused on route planning for school vehicles, real-time route guidance, intelligent bus stops, location tracking, school vehicle monitoring, warning system around school buses, training schemes for stakeholders (Aigner-Breuss et al. 2010, Anna et al. 2012). However, information in respect of coach/bus operations and safety compliance were not provided. (Kotoula et al. 2017a) reviewed the existing school transport framework in Greece and compared the standard with the other European countries. However, the safety-related issues in a coach-based school travel are not identified. Only the managerial issues were presented.

2.3.2 Safety of Children in School Buses/Coaches

Qatar government conducted a study on school transport in 2012 to improve the safety of children in their country. The main aims of the study were, assessing the stakeholder's (schools and parents) perspective on school transport, identifying their vision and goals for the safety of school transport, reviewing international norms for school transport and comparing it with their existing norms. However, information about the coach compliance safety and safety of children on school trips was not included in the study (RAND-Qatar Policy Institute 2012). Edmonston and Sheehan (2001) reviewed the school transport safety in New Zealand and proposed safety recommendations to the government. This resulted in the development of a tool named "School transport safety matrix", which was built using Haddon's matrix (William 1972). It conceptualized safety issues in school transport by coaches. A study conducted by (Ipingbemi and Aiworo 2013a), detailed various safety and security issues of school children making a journey to school. Only the safety issues faced by children who walk to school was presented and safety related issues with coach transport were not explored. A study conducted in the United States revealed that there is a need for better understanding of the safety of children travelling on school buses for school trips (Beck and Nguyen 2017b).

2.4 *Related Technologies*

Technology innovations (Faraj et al. 2014, Huang et al. 2014, Silva et al. 2015) in School Transport Systems (STS), gave birth to Intelligent School Transport Systems (ISTSs), which addressed some of the issues (Falkmer et al. 2014, Harrison et al. 2014, Mammen et al. 2015) in STS such as optimal routing of school vehicles, continuous monitoring of school buses and children. An ISTS incorporates the innovation and adoption of recent technologies to create applications for the benefit of school transport. Major technologies involved in ISTS are school bus route planning systems, school vehicle-children tracking and monitoring systems. Figure 2.1 shows the functions of a typical ISTS.

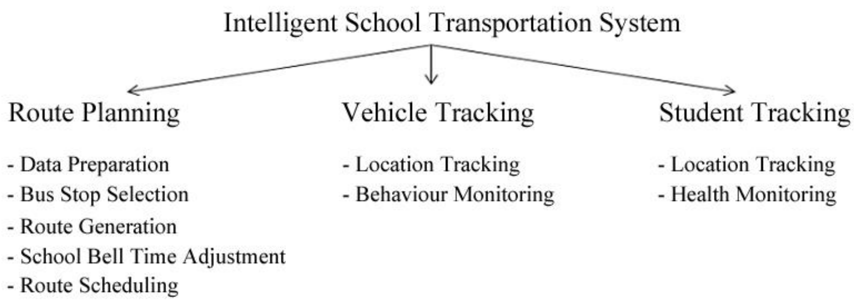


Figure 2.1 - Functions of a typical Intelligent School Transport System

2.4.1 *Route Planning Systems*

In schools, manual route planning is an intensive task and it consumes a considerable amount of time for selecting appropriate safety routes, as well as the number of buses required for a route. Typically, school transport departments perform manual route planning at the beginning of each term due to the changes in the number of children using the service. To make this process more efficient, automated route planning systems are used. School bus route planning systems rely on the history of School Bus Routing Problems (SBRPSs), which have been studied since the first published work by Newton and Thomas in 1969 (Newton and Thomas 1969). There are only limited publications available for reviewing school bus routing problems (Desrosiers et al. 1981, BRACA et al. 1997, Park and Kim 2010). Junhyuk and Byung-in Kim (Park and Kim 2010) describe school bus routing problems for a fleet of school buses as an efficient schedule planning, where children are picked up by each bus from various geographical locations and delivered to their respective schools while satisfying a set of constraints. According to Desrosiers et al. **(**1981), there are five steps to reduce school bus routing problems, namely, Data Preparation (DP), Bus Stop Selection (BSS), Bus Route Generation (BRG), School Bell Time Adjustment (SBTA) and Route Scheduling (RS). It also includes Transportation Costs (TC), Total bus travel distance (TBD), Number of buses used (N), Total student riding distance or time (TSD) and Load balancing (LB). Table 2.1 shows a comparison of methods applied by various researchers since 2010 for reducing school bus routing problems. The constraints that are categorized to minimise school bus routing problems are also shown in Table 2.1. They are, Vehicle Capacity (VC) – number of children allowed for a vehicle, maximum Ride Time (RT) – travel time of each child, school Time Window (TW) – arrival time of vehicle at school, maximum Walking Distance (WD) – distance between children home and bus stop, minimum number of Children for a Route (SR), Passenger Demand (PD) – route request by children during travel, maximum Bus stops Visited (BV), maximum Waiting Time (WT) – allowed waiting time for children at the bus stop and Terrain Type (TT) – type of road selected.

Table 2.1 - Recent Works in School Bus Routing Problem (2010-2016)

Study	**Considered school bus routing problem sub Problems**	**Constraints**	**Method**	**Goal**

Euchi and Mraihi (2012)	BSS,BRG,RS	VC,RT,PD	Artificial ant colony with variable neighbourhood local search algorithm	Minimizing the total number of buses required
Riera-Ledesma and Salazar-González (2012)	BSS,RG	VC,WD	Branch and cut approach based Exact algorithm	Number of routes and route length minimization
Pacheco et al. (2012)	RG,RS	RT	The multi-objective adaptive memory programming	Minimizing the duration of the longest routes and total distance travelled
Kim et al. (2012)	RS	TW	Branch and bound approach based on assignment problem	Optimization of bus schedules to serve all the given trips within the given TW
Park et al. (2012)	RG,RS	VC,RT,TW	Mixed load improvement algorithm	Minimizing the total number of buses required
Schittekat et al. (2013)	BSS,RG	VC,TW,SR,WD	GRASP+VND metaheuristic approach	To integrate BSS and RG through meta-heuristic approach with simplified implementation
Riera-Ledesma and Salazar-González (2013)	BSS,RG	VC,RT,SR,BV,WD	Set partitioning formulation based branch	Minimizing the number of routes, route length and

			and price algorithm	walking distance
Kinable et al. (2014)	BSS,RG	VC,SR,RT	Exact branch and price framework	Minimizing the routing costs
Bogl et al. (2015)	BSS,RG,RS	VC,WD,WT	Heuristic solution framework allowing transfers	Minimizing the operational costs
Chen et al. (2015)	RG,RS	TW,RT	Exact mixed integer programming and two-stage metaheuristic method	Minimizing the number of routes and total number of buses
Silva et al. (2015)	RG,RS	VC,TT,SR,WD	Mixed load approach	Minimizing the total travelled distance of a heterogeneous fleet
(Caceres et al. 2017)	N, TBD	VC,RT,WT, WD	Cascade simplification algorithm & column-generation-based algorithms	Solving the problem of overbooking in SBRP
(Miranda et al. 2018)	TC	VC,TW,RT,WD	Multi-load model	Minimising the cost of the transport without compromising efficiency.

2.4.2 Vehicle Tracking Systems

Parents spend more time on the streets and making phone calls while waiting for school buses due to the unpredictable nature of the traffic, particularly during the winter months. For this reason, vehicle-children tracking systems were made. School vehicle-children tracking is a process of tracking the school bus and children inside it using tracking devices such as the Global Positioning System (GPS) (Anund and Dukic 2011) and Radio Frequency Identification (RFID) systems tags (Shaaban et al. 2013), which are commonly used in tracking technologies. The tracked data may be utilized by school transport departments and also shared with parents to inform them of the location of their children.

School vehicle tracking is similar to common vehicle tracking which involves the use of GPS devices to track the vehicle. A GPS device in the school vehicle automatically provides updates of its location coordinates to a cloud server, which processes and plots these coordinates on a virtual map. This map can be accessed by the stakeholders (transport department and parents) for information about the location of the school vehicle. School vehicle tracking systems can be utilized for two purposes: Vehicle Location Tracking (VLT) and Vehicle-Driver Behaviour Monitoring (VDBM). Table 2.2 shows the characteristics of school vehicle tracking and monitoring systems. The main focus in the table is the different types of vehicle tracking systems used in ISTS.

Table 2.2 - School Vehicle Tracking and Monitoring

Study	**Sensor type**	**Type of tracking considered**	**Nature of tracking**	**Goal**
Anund and Dukic (2011)	Active RFID	VLT	Lag time	To monitor bus location and providing bus time information to parents
Shaaban et al. (2013)	GPS	VLT	Real-time	To smartly track the school bus and share the location info with parents

Zambada et al. (2015)	GPS,accelerometer	VLT, VDBM	Real-time	Increasing the safety of school bus monitoring through the Internet of Things (IoT)
(R et al. 2018)	GPS/IRNSS	VLT	Real-time	To track the location of the school bus
(Takalikar et al. 2018)	Active RFID, GPS	VLT, VDBM	Real-time	To track the location of the school bus and to monitor the driver alertness.

2.4.3 Children Tracking Systems

Similar to bus tracking, children tracking also employ similar technologies which are used to traverse the accurate placement of children. RFID is commonly employed for children tracking (Al-lawati et al. 2015). The children tracking system can be classified into two types: location tracking (Student Location Tracking (SLT) & In-Vehicle-Attendance (IVA)) and Health Monitoring (HM). Table 2.3 shows the characteristics of school children tracking and monitoring systems.

Table 2.3 - School Children Tracking and Monitoring

Study	**Sensor/Technology used**	**Type of tracking considered**	**Nature of tracking**	**Goal**
Anund et al. (2010)	RFID	SLT, IVA	Active	To track and monitor the school children inside the school bus
Saranya and Selvakumar (2013)	GPS	SLT	Active	To track the location and emotional status of the children
Shaaban et al. (2013)	RFID	SLT	Passive	To track and monitor the

				children during their trip to and from school on the school bus
Huang et al. (2014)	GPS/Bluetooth	SLT	Active	To develop a mobile-based child security monitoring system in school travel
Al-lawati et al. (2015)	RFID	SLT, IVA	Passive	To track the children location and monitoring bus boarding times
Collins et al. (2015)	GPS/Heart rate	SLT, HM	Passive	To monitor the children physical activities from school to home travel
(Hemalatha et al. 2017)	RFID	SLT, IVA	Active	To track the children location along with speed of the vehicle and alcohol consumption by the driver
(Takalikar et al. 2018)	RFID	SLT, IVA	Active	To track the location of the children by recording the entry and exit the school bus.

2.5 School Transport in the UK

Schools in the UK can be divided into 3 categories. Pre-school (where toddler spending their time in the nursery), primary (aged around 5 to 10) and secondary school (aged around 11 to 16) (BBC 2017a). According to the Department for

Education of the UK, there are in total of 8.67 million pupils studying in 24,281 UK schools (Drake 2016). Children in the UK use various modes of travel to primary and secondary schools. Based on the Transport Statistics of Great Britain 2017, in the age group of 5-10, 51% of the children walk to school, 41% go by car, 6% use public transport (includes coaches) and 2% cycle to school. In the age group of 11-16, 39% of the children walk to school, 31% use public transport (includes coaches), 26% go by car and 3% cycle to school (DfT 2017b).

2.6 School Transport Coaches

School transport via coaches can be divided into two types, Home to School Services (HSS) and other activities which require Occasional Coach Hire (OCH) (field trips, sports matches, etc.). In HSS, coach operators plan the routes before the start of school term and advertise the service and its routes. Parents, who find it suitable for their children, adopt the service. OCH, on the other hand, can possibly involve transporting children from one council to another or from one region to another or from one country to another. Transporting children, of any age for school trips is considered a high-risk activity (Department for Education 2014). This is especially true when using an external supplier to provide the transport, as the level of risk will naturally increase when engaging a third party that is not directly under the control of the school.

Despite the fact that bus or coach travel in the UK is deemed a safe mode of transport, news reports of children being injured or even killed in bus and coach crashes have been reported (Espinoza 2015, Bishop and Campbell 2016, Fox and Bumett 2016, BBC 2017b, 2018). This alarmed the safety professionals and the UK government. The UK government has been trying to improve safety in school transport through research-based policy updates (Department for Education 2014). Coach accidents are still happening despite strict regulations set by the government. Compared to the other modes of travel to school, there is only limited research available which relates to coach-based transport in the UK (Van Ristell et al. 2014). To investigate the current safety of children travelling in coach-based school transport in the UK, the literature review is carried out in four steps.

i. To identify the number of coach accidents involving children occurred in the UK, accident analysis is carried out using the data available from the STATS19 database (DfT 2017a).
ii. Common contributory factors for the coach accidents were identified using contributory factors for reported accidents-database (DfT - Ras50005 2017);
iii. To understand the measures taken by the government to reduce/prevent accidents, the UK government policies and guidelines were reviewed
iv. If the UK coach operators fail to follow the government guidelines, they were suspended or their licences were revoked (Commissioners 2017).

2.7 Accident Analysis

2.7.1 STATS 19 Database

Road vehicle accidents are well documented in an official database called STATS19 - (DfT 2017a) which contains accidents reported in the UK. It is updated annually during September of each year. The STATS19 database has three different datasets named accident data, collision data and causality data. The data is collected based on the regions in the UK (South East, London, North West, East of England, West Midlands, South West, Yorkshire & the Humber, East Midlands, North East, Scotland government regions and Wales government regions). The data from the STATS19 database was used to analyse the coach accidents involving children. The statistics relate only to personal injury accidents on public roads that are reported to the police and subsequently recorded, using the STATS19 accident reporting form (ManchesterCouncil n.d.). Information on damage-only accidents, with no human casualties or accidents on private roads or car parks, is not included in this data.

2.7.2 Accident Statistics

The following logical criteria were used for extracting information from the STATS19 database using the MAST analysis tool (MAST 2018). Criteria - accidents involved a coach which was undertaking a journey with the specific purpose of taking pupils to or from school (HSS) during Monday to Friday, either 7AM to 9AM or 3PM to 5PM OR outside weekday normal hours (such as to or from extra-curricular activities – Excursion trips OCH) AND at least one passenger on that coach suffered an injury.

Table 2.4 illustrates the outcome of the analysis of accidents occurred between 2005 and 2016. There were 381 accidents in total and 618 vehicles were involved which resulted in 1218 child casualties. Although the number of accidents and causalities are slowly decreasing as shown in Figure 2.2, there are still a considerable number of coach accidents which are occurring.

Table 2.4 - Coach Accidents in the UK (2005-2016)

Year	**Number of Accidents**	**Number of Vehicles Involved**	**Number of Causalities**
2005	58	89	144
2006	54	92	168
2007	36	66	138
2008	42	69	105
2009	39	62	110
2010	32	48	132
2011	31	51	110

2012	27	42	83
2013	13	21	53
2014	21	31	102
2015	18	32	46
2016	10	15	28
Total	**381**	**618**	**1218**

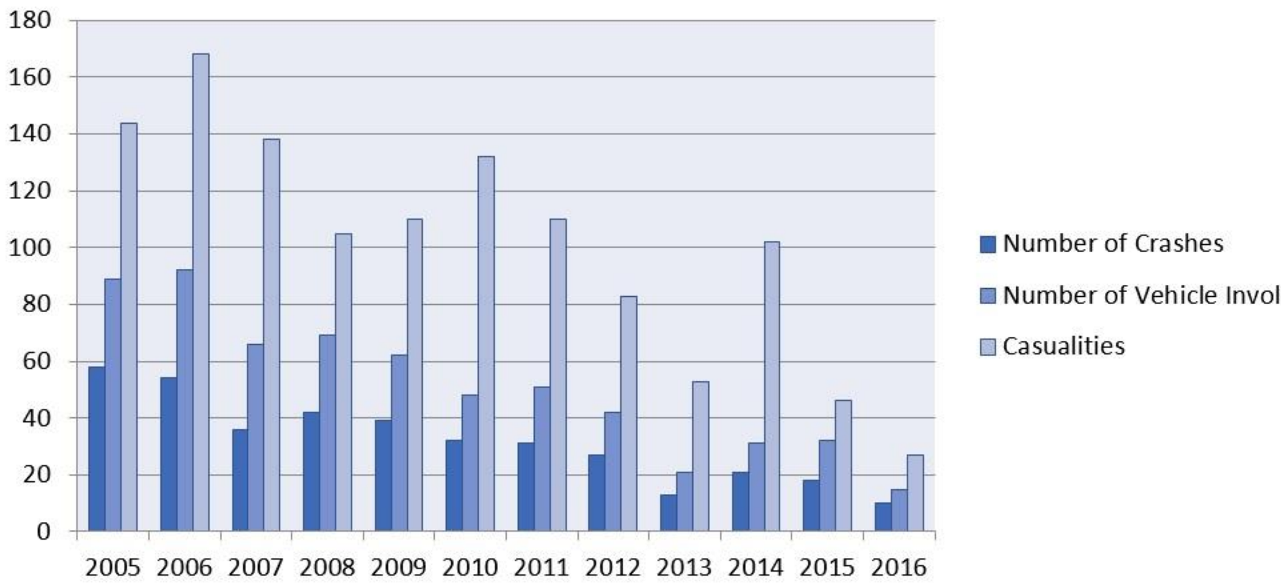


Figure 2.2 - Coach Accidents in the UK (2005-2016)

2.7.3 Contributory Factors Analysis

According to the Department for Transport (DfT) in the UK, driver errors or technical faults in the vehicle were the most commonly reported factors contributing in all coach accidents (DfT - Ras50005 2017). The government has requested strict regulations to be applied, particularly by the Private Sector Vehicles (PSV) and ordered Driver and Vehicle Standard Agency (DVSA) to inspect the coach operators regularly for their compliance with the government regulations.

2.8 Government Policies and Guidelines

In 2010 the Scottish government commissioned a Transport Research Laboratory (TRL) to develop guidelines, policies and procedures for safety in school transport (Kinnear and Smith 2010). In-depth case studies were carried out with Scottish local authorities to develop safety guidelines and policies. Subsequent after applying and using the guidelines and policies for two years, TRL reviewed their effectiveness and explored ways in which they could be improved (Hutchins and Kinnear 2012). As TRL was considering many aspects of school transport, an in-depth investigation in respect of the safety of hired coaches was not carried out. In 2014, the English government launched a new home to school travel and transport guidance for local authorities, parents and other interested parties (Department for Education 2014). Again, no criterion for selecting coach operators for school trips was included in the guidance. There are 217 councils present in the UK (England – 152, Scotland – 32, Whales – 22 and Northern Ireland – 11). Most of the councils follow the national home to school travel and transport guidance. But some councils modify the national guidelines and create an enhanced version of it to suit them (Van Ristell et al. 2014). Particularly, Northamptonshire council has a checklist for the operators where they require the operators to sign it and pass it on to the school Headmaster before the journey (NorthamptonshireCountyCouncil 2016). The checklist helps the operators to self-comply regarding the coach's and driver's fit for purpose. Again, it is self-compliance and there are possibilities the operators may just sign it without verifying things mentioned in the checklist.

2.9 Traffic Commissioner Report Analysis

Traffic commissioners are responsible for licensing, inspecting and verifying operators of Heavy Goods Vehicles (HGVs) and Public Service Vehicles (PSVs) in the UK. Regulatory actions may be taken against operators such as revoking, suspending or curtailing the operator's license (DVSA 2011). Thus, during the period 2005 to 2017, 783 operators' licenses have been revoked without a public inquiry (Commissioners 2016). Every year, traffic commissioners publish a report (Commissioners 2017). Table 2.5 and Figure 2.3 shows the summary of traffic commissioners' report for 2005 to 2017. Inspectors from Vehicle and Operator Service Agency (VOSA) examine vehicles at random places or by surprise visits to coach companies. (VOSA was replaced by Driver and Vehicle Standards Agency DVSA in April 2014) (VOSA - DVSA 2014). They have the right to take any vehicle off the road if they suspect that the vehicle is not fit for the purpose or if there is anything wrong with the driver (DVSA 2011). As inspecting all the coach operators is not feasible, it is difficult to assume that coaches used for school transport are always safe.

Table 2.5 - Traffic Commissioners' Reports (2005-2016)

Year	**Number of Public inquiries**	**License suspensions**	**License revocations**	**License Disqualification under 1985 Act**
2005-06	179	10	49	13
2006-07	155	16	38	10
2007-08	193	14	55	15
2008-09	207	17	64	19
2009-10	180	15	63	21
2010-11	199	2	57	6
2011-12	191	17	71	12
2012-13	180	15	61	15
2013-14	231	22	75	14
2014-15	252	23	97	24
2015-16	162	15	75	13
2016-17	148	7	78	23
Total	**2277**	**173**	**783**	**185**

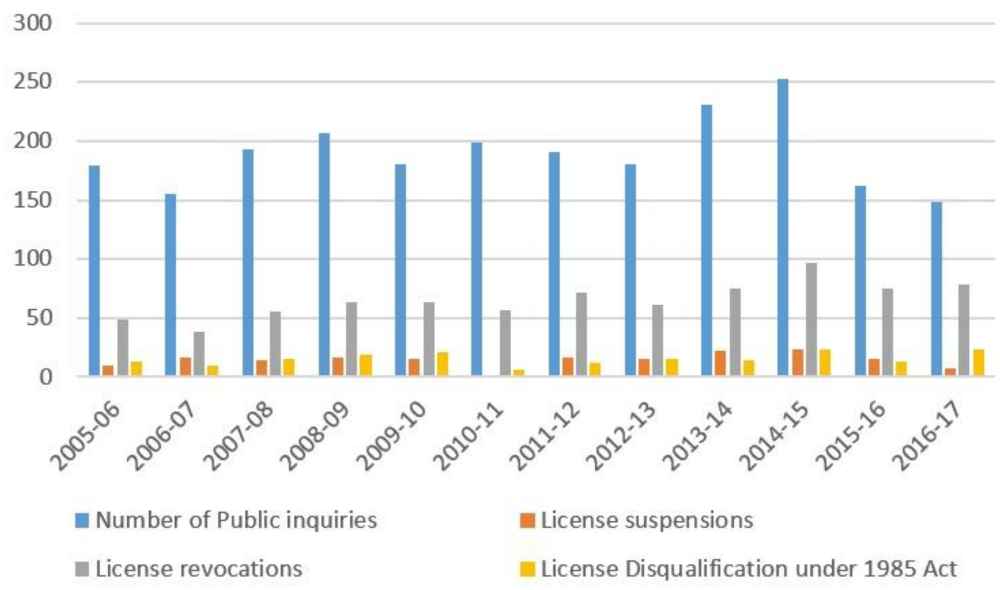


Figure 2.3 - Traffic Commissioners' Reports (2005-2017) (Commissioners 2017)

2.10 Research Gap

Safety of school transport is a critical issue which should be addressed. Research on the safety of children travelling by coaches/buses is not given a high priority in the UK compared to the other modes of transport. However, coach accidents are still happening. The major contributory factors for these accidents were faults in the vehicle and driver error. These occur due to improper maintenance and operators' non-compliance with safety regulations. The UK government is aware of these issues and have strict regulations in place for the operators to maintain their fleet's safety level. But, even having strict regulations, coach accidents are still happening. Traffic commissioners take strict approaches to ensure that all coach operators remain compliant with the safety regulations. As a result, they revoke the licences of the coach operators who fail to comply with the safety regulations. During the course of this research, and through the analysis of the traffic commissioner's reports, it has become apparent that not all the coach operators are compliant with the regulations all the time. This problem is not addressed in any of the academic literature. The existing literature so far has focused on different aspects of school transport. Most of the available evidence are in the form of the government reports. To address this research gap, the safety level of the coach-based school transport in-terms of its operation and safety compliance have been investigated in this thesis. This is achieved through an exploratory research method which is discussed in the next chapter.

2.11 Chapter Summary

Safety in hired coaches by schools in the UK is a less investigated area, compared to the other modes of transport to school. Limited literature has examined the safety of children travelling via coaches/buses around the world with respect to operations and safety compliance. Studies related to the coach-based school transport Worldwide, Europe and in the UK were reviewed. History of coach accidents involving children been retrieved from the STATS19 database and the contributory factors for the coach accidents were analysed. Government policies and guidelines to reduce these accidents were reviewed. Analysis of traffic commissioner reports showed that the problem is not with the existing regulation but with the coach operator non-compliance. There is no existing work addressing this problem. It is evident from the literature that there is no specific safety framework available to ensure the safety of children travelling by coaches in the UK and there is a need for a further in-depth investigation.

Chapter 3
Methodology

3.1 Introduction

This chapter presents details of the research methodology used in this study. Sequential mixed-method exploratory research (qualitative survey followed by a quantitative survey) was used followed by analysis, which is presented in this chapter. For an overview of the research methodology, please refer to Figure 3.1 and 3.2.

3.2 Research Philosophy

Research Philosophy is the way in which data for a phenomenon is gathered, analysed and used. According to Saunders (Saunders et al. 2008), Research Philosophy can be classified into 4 types, Positivism, Realism, Interpretivism and Pragmatism. To determine the research philosophy for this study, Heightening your Awareness of your Research Philosophy (HARP) tool proposed by (Saunders et al. 2008) was used. By using the HARP tool, Interpretivism was selected as research philosophy. Interpretivism integrates human interest into a study. According to Saunders, "Interpretivism advocates that it is necessary for the researcher to understand differences between humans in our role as social actors. This emphasizes the difference between conducting research among people rather than objects such as trucks and computers" (Saunders et al. 2008). The variations of Interpretivism include phenomenology and symbolic interactionism. In this research, to understand the phenomena behind hiring the coaches for school trips, phenomenology research philosophy was followed. Phenomenology is the process of humans making sense out of the world around us. Some would argue that interpretivist perspective is highly appropriate in the field of organizational behaviour that using phenomenology. Not only are they complex but also unique (Saunders et al. 2008). Most of the relevant study in school transport used Interpretivism as their research philosophy to explore underlying phenomena (Anund et al. 2010, Awuahaddor et al. 2013).

Research Approach: It can be divided into inductive and deductive approaches. Inductive approach is the process of collecting data (qualitative) and developing a theory as a result of data analysis. The deduction is the process of testing a theory (i.e) moving from theory to data (quantitative) (Saunders et al. 2008). This research employs both the inductive (Phase 1) and deductive approaches (Phase 2) as shown in Figure 3.2 and 3.3.

Research Strategy and choice: Research Strategies can be classified into case studies, surveys, experiments, action research, grounded theory, ethnography and archival research (Saunders et al. 2008). In this research, qualitative case study (semi-structured interviews) and a quantitative survey (online) were selected as our research strategies. These two strategies are put together in a sequential exploratory mixed method research design (Ivankova et al. 2006, Hesse-Biber 2010, Berman 2017) which reflects mixed-method as our research choice. The detailed explanation of the mixed-method research design employed in this research and the justification of the selection of research strategies and choices are given in section 3.4.

Time horizon: Time horizons determine the nature of the data collection process. It is classified into two types, cross-sectional and longitudinal. If a research study about "snapshot" taken at a particular time then it is called as cross-sectional. Longitudinal studies are study of events that take place over a given period of time (i.e) more of akin to a diary or a series of snapshots over a given period. Based on the research questions, this study analyses event happened at a particular time. So, cross-sectional was chosen as our time horizon. Cross-sectional studies often employ survey strategy (Easterby-Smith et al. 2012, Robson and McCartan 2016).

3.3 Research Methodology

To develop the research methodology, the research onion proposed by (Saunders et al. 2008) was used. This method is commonly used by the ITS and other researchers around the world to effectively construct their research methodology in Transport Systems (Mulugeta 2017, Björsell and Hedman 2018, Eltahan et al. 2018, Lew et al. 2018, Skok and Baker 2018). Each layer can be viewed as a series of steps in which each step describes a more detailed stage of the research process. In the first step, the research philosophy is identified followed by the identification of research approaches. The research strategies are identified next, followed by the method of choices and the time horizons. Finally, the data analysis method is used. The advantage of using the research onion is that with its series of steps, it is easy to understand different types of data collection methods. It also shows the steps by which a methodological study can be described (Saunders et al. 2008). Figure 3.1 shows the research onion. The methods used for this research are circled in the diagram in this figure.

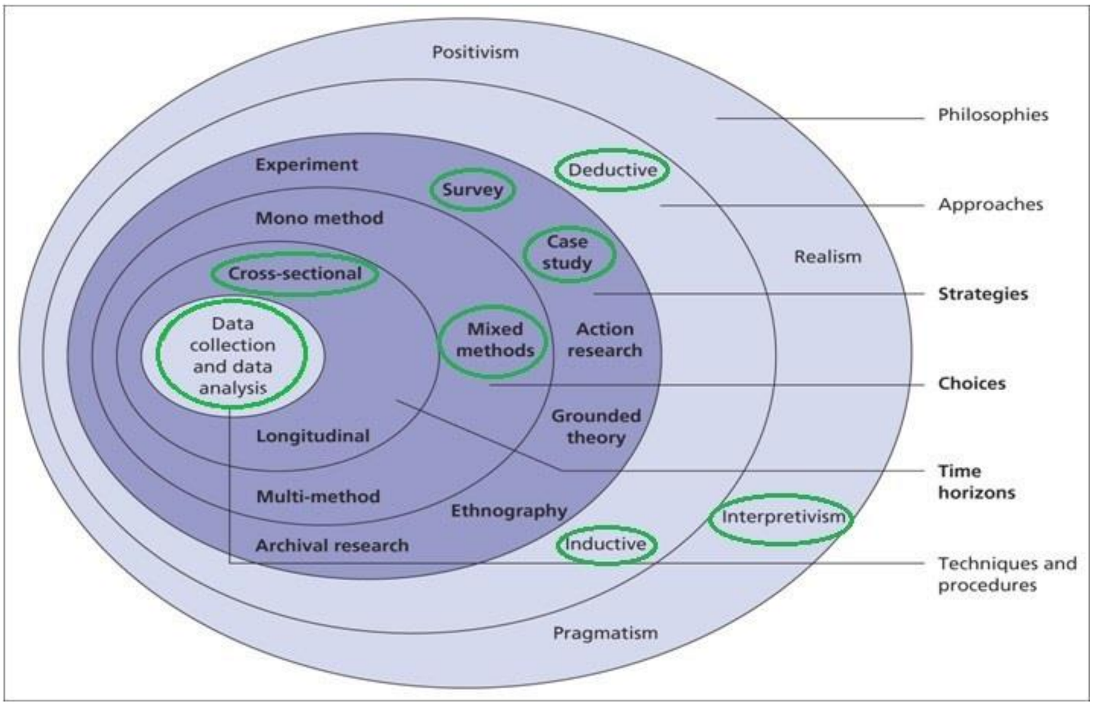


Figure 3.1 - Selection of Research Methodology – Research Onion (Saunders et al. 2008)

Based on the above, the methodology for this thesis is formulated as shown in Figure 3.2. An in-depth literature review was conducted followed by a qualitative survey and analysis. To further investigate the findings, a quantitative survey was conducted and analysed. Based on the research outcome, a safety transport framework was created. Subsequently, a prototype was developed, tested and evaluated alongside with the framework.

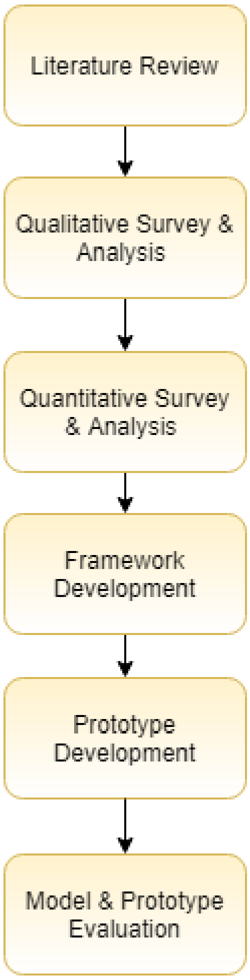


Figure 3.2 - Methodology Overview

3.4 Sequential Exploratory Research Design

Going by the accident statistics in the UK which are recorded in STATS19 (DfT 2017a), traffic commissioners' reports and the lack of literature on coach-based school transport, it is apparent that there is a need for a further and an in-depth investigation of the existing safety of children travelling by hired coaches in the UK. For this investigation, a sequential exploratory mixed-method research was utilised (Ivankova et al. 2006, Hesse-Biber 2010, Berman 2017). The research included two phases. The first phase was to collect qualitative data followed by analysis and in the second phase, quantitative data was collected and analysed. Figure 3.3 shows these phases. The detailed explanations of these phases are given in section 3.5 and 3.6.

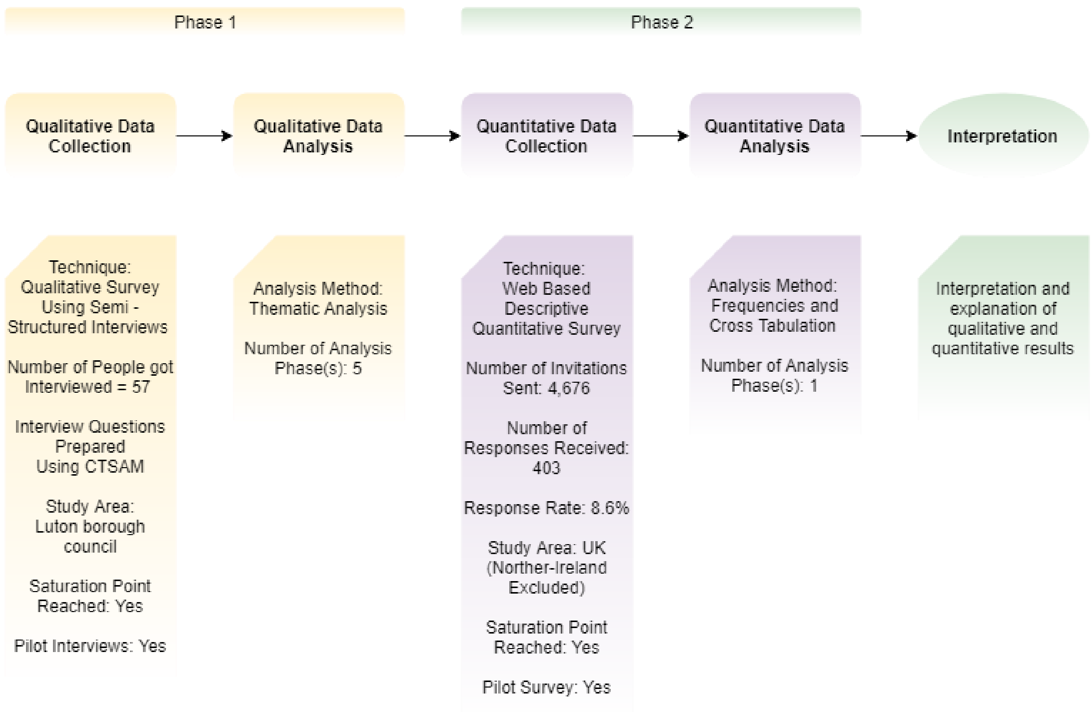


Figure 3.3 - Sequential Exploratory Mixed-Method Research

3.5 Phase 1 – Qualitative Survey

3.5.1 Survey Design

Qualitative survey methods may be of the types structured interviews, semi-structured interviews, unstructured interviews, focus groups, direct observation, participant observation, written documents, and artefact study (Gill et al. 2008, Rich et al. 2018). The semi-structured interview was selected as our survey method as it is the most appropriate for phenomenology research (Gill et al. 2008, Saunders et al. 2008, Brannen 2017). The objective of this survey was to understand the phenomena and problems related to hiring coaches for transporting schoolchildren and to identify safety-related issues. Luton Borough Council in East of England was selected as a geographical area for the survey. East of England has had more coach accidents and operator license revokes, compared to other regions. Stakeholders were selected based on their experience in handling schoolchildren and also the coach transport industry.

Table 3.1 illustrates the number of stakeholders who participated in the survey (stakeholder distribution). In total, 270 invitations were sent for to different stakeholders and 57 agreed to participate in the survey. Some of the participants requested an online questionnaire instead of being interviewed. In this case, they were provided access to an online questionnaire. The questions in the questionnaire were identical to those asked at the interviews.

Table 3.1 - Stakeholder Distribution

	Transport Sector	**Social Sector**	**Educational Sector**	**Government Sector**
Semi-Structured Interviews	Coach Operators – 12	Parents – 17	School Headmasters – 12	Council transport head – 2
	Drivers - 13			Road safety analyst - 1
Total	25	17	12	3
				Total: 57

3.5.2 Coach Travel Safety Analysis Matrix (CTSAM)

To support the semi-structured interviews, a holistic interview topic matrix based on Haddon Matrix (William 1972) which is named in this thesis "Coach Travel Safety Analysis Matrix (CTSAM)" was developed. CTSAM is used as a tool for creating questions for qualitative interviews. Each coach trip is classified into three phases, Pre – journey (before the trip), journey (during the trip) and post – journey (after the trip). The trips were categorised into these based on the three factors Human/Host, Agent/Vehicle and Physical Environment. Within the CTSAM, various issues relating to school transport with respect to journey-phases are listed. Table 3.2 shows the categories which are based on the current coach-based school transport in the UK.

Table 3.2 - Coach Travel Safety Analysis Matrix (CTSAM)

Journey sequence	Human/Host	Agent/Vehicle	Physical Environment
Pre Journey	• Accident Awareness • Safety Measures • Driver Check • Children Safety	• Vehicle Safety • Safety Measures • Children Safety	• Coach Operating Environment and Procedures • Route Safety • Children Safety
Journey	• Children Safety • Children Behaviour Issues • Stakeholder Communication	• Problems During Travel • Vehicle Issues	• Environment and Other Problems
Post Journey	• Children Safety • Communication Problems • Preventions, Suggestions & Future Enhancements	• Emergency Procedures	• Pickup/Drop Bus Stop Issues

A. Pre-Journey

This phase relates to all the activities which take place before the trip. Analysing pre-journey activities help to identify issues that arise before the trip. Topics in this phase help the investigators to identify the root cause for accidents and ways to prevent them. This phase covers topics which include accident awareness, safety measures taken, driver safety, children safety, vehicle safety, route safety and the operating environment.

B. Journey

This phase relates to all activities that take places during a trip, which include children safety, stakeholder communication, and issues faced during travel. By investigating the journey phase, internal/external issues that lead to a coach accident can be identified. It also helps in identifying the issues that may arise during the trip.

C. Post-Journey

This phase relate to issues, which relate to the activities that take place after the trip. Analysing post–journey activities helps the investigator to identify the stakeholder's experience of the trip. This phase covers topics, such as children safety, experiences, suggestions, issues and the requirements of stakeholders and emergency in the event of accidents. This phase helps the investigator to provide suggestions for improvements.

3.5.3 Pilot Interviews

CTSAM was used to aid compiling questions for the interviews. Two experienced stakeholders from each sector (Transport sector, Educational sector and social sector) were asked to provide feedback on the suitability of the draft questions and their recommendations were incorporated (Appendix 1 and 2).

3.5.4 Interviews

Participants were provided with a short introduction about the research prior to the interview. Their consents to participate and to audio record, the interview was obtained using a consent form. The interview was only conducted after the participant agreed to participate and signed the consent form (Some of them refused their voice to be recorded and sign the consent form but agreed to be interviewed anonymously).

3.5.5 Survey Analysis

Interview audio files were manually transcribed. The data analysis methodology (thematic analysis) which has 6 steps, proposed by Braun and Clarke (2006 and 2013) was followed using Nvivo. Step 1 is to familiarize with the data (i.e transcribing and importing data). Step 2 is open coding in which initial codes are generated from the imported data. In Step 3, categories are developed by reordering initial codes. In Step

4, categories are reviewed and in Step 5, themes are defined and named (further refinement of themes and analysis). Final Step is the write-up.

Step 1: Familiarize with the data

It involves, transcribing and noting down initial ideas by reading and re-reading interview data. The transcribed text files and survey files are imported into the internals folder. Once the data is imported, the case files and classifications are created**.** Figure 3.4 shows the organization of folders in Nvivo.

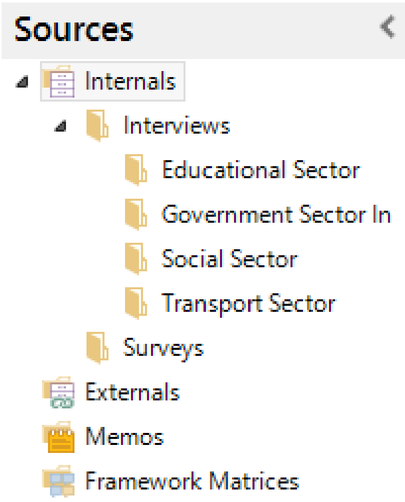


Figure 3.4 - Organization of folders in Nvivo

Step 2: Generating Initial codes (Open Coding)

The initial codes are generated based on an open coding technique. The interview guide prepared for the qualitative interviews relates to this step. The open coding is done using the categories listed in Figure 3.6 as a reference. Figure 3.5 shows the open coded data where Sources represents the number of stakeholders and references represents number of times a particular word or sentence mentioned by the stakeholders.

Name	Sources	References
Pre-Journey	26	302
Vehicle Safety (quality of vehicle)	26	85
Route Safety	19	57
Children Safety	19	57
Others	17	42
Causes for accidents	16	20
Driver skills (quality of driver)	16	41
Post-Journey	26	105
Suggestions to improve safety	25	63
Experiences	10	39
Children safety	1	3
Journey	14	51
Children safety	13	21
Stake holder communication	7	15
Driver conerns	6	15

Figure 3.5 - Open coded data

Step 3: Searching for Categories

Once the initial coding is done, possible categories within the initial codes are developed by re-ordering them. Categories could be described as halfway between initial codes and themes. Figure 3.6 shows the list of the categories from the initial codes.

Name	Sources	References
Unaware of driver and vehicle condition	24	55
Vehicle tracking	17	27
Need for bus escorts	15	38
Mechanism to know driver and vehicle status	11	20
Children behaviour (bus stop, inside bus)	11	39
Schools need to check the vehicle and driver	10	11
Supervise student at bus stops	10	13
Time delays by parents-drivers (lateness)	10	18
Inexperienced driver (driver error)	8	14
CCTV Cameras	7	13
Vehicle out of control (vehicle error)	7	12
Need proper driver - passenger education	6	8
Driver got disturbed by puils in bus	6	13
Other vehicle behaviour around the bus(External Factors)	6	7
Avoid tight road or tight bend	6	8
Routes with brighter bus stops	6	7
Student tracking	5	6
Prefer motorways	5	7
21 hours double team journey	4	7
Driver Fatigue	4	12
Driving hours (real rest time)	4	7
No prior training to driver handling school kids	4	4
Speed limits	4	6
Need for legislation to stop people distracting driver	3	6
Shortest route possible	3	5
Safe driver	2	3
Software to manage driving hours	2	2
Drivers not given with proper rooms to stay	2	4
Avoid traffic (dynamic)	2	3
Bus stops not in a busy road	2	2
Bus or Coach should be on time	1	2
Driver didn't do proper daily check	1	1
Guidelines are not followed strictly	1	1
Terrain type (Routes)	1	1
Overloading buses	1	2
Driver misbehavior	1	1
Budget for school transport is low	1	1

Figure 3.6 - Categories from the initial codes

Step 4: Reviewing Categories

This Step involves in-depth understanding of highly qualitative aspects of data by breaking down the constructed categories into sub-categories. The relationship between the categories and insights into the meanings embedded in are analysed.

Step 5: Defining and Naming Themes (Data Reduction)

In this Step, the codes from the previous steps are consolidated in an abstract manner. This step helps in sorting the existing categories into two major themes (issues and requirements). It indicates the needs and problems of the stakeholders. Figure 3.7 shows the final codes that are identified under two themes (problems and requirements) with the categories listed.

Name	Sources	References
Requirements	27	187
Vehicle tracking	17	27
Need for bus escorts	15	38
Mechanism to know driver and vehicle status	11	20
Supervise student at bus stops	10	13
Schools need to check the vehicle and driver	10	11
CCTV Cameras	7	13
Need proper driver - passenger education	6	8
Avoid tight road or tight bend	6	8
Routes with brighter bus stops	6	7
Student tracking	5	6
Prefer motorways	5	7
Speed limits	4	6
Need for legislation to stop people distracting driver	3	6
Shortest route possible	3	5
Software to manage driving hours	2	2
Safe driver	2	3
Bus stops not in a busy road	2	2
Avoid traffic (dynamic)	2	3
Bus or Coach should be on time	1	2
Issues	27	199
Unaware of driver and vehicle condition	24	55
Children behaviour (bus stop, inside bus)	11	39
Time delays by parents-drivers (lateness)	10	18
Inexperienced driver (driver error)	8	14
Vehicle out of control (vehicle error)	7	12
Other vehicle behaviour around the bus(External Factors)	6	7
Driver got disturbed by puils in bus	6	13
Driver Fatigue	4	12
21 hours double team journey	4	7
Driving hours (real rest time)	4	7
No prior training to driver handling school kids	4	4
Drivers not given with proper rooms to stay	2	4
Driver didn't do proper daily check	1	1
Terrain type (Routes)	1	1
Guidelines are not followed strictly	1	1
Budget for school transport is low	1	1
Driver misbehavior	1	1
Overloading buses	1	2

Figure 3.7 - Categories and themes

Step 6: Write up

This Step involves summarising the categories and proposing empirical findings which are presented in chapter 4.

3.6 Phase 2 – Quantitative Survey

3.6.1 Survey Design

To further investigate the issues identified in the qualitative survey, a quantitative survey was carried out across the UK. People who fitted in the categories of the stakeholders in the previous survey (Parents, Teachers, School Headmasters, Coach Operators, Drivers, Council Transport Officers and Road Safety Analysts) were invited to participate. Table 3.3 shows the information which is obtained from the government databases (DfE and National Statistics 2017)(Scottish Government 2015, Commissioners 2017)(DVLA 2017a, Welsh Government 2017).

Table 3.3 - Total Population Size

	Children (Parents)	**School**	**Operator**	**Driver**	**Council**
England	8,560,000	24,288	7,503	393,382	353
Scotland	684,415	2,524	971		32
Wales	104,959	1,574	858		22
Total	9,349,374	28,386	9,332	392,382	407

Table 3.4 shows the minimum required sample size what is calculated based on the recommendation of (Bernard 2010, DCED 2018) using equation 3.1.

$$s = (z^2\ (p(1 - p))/\ e^2)\ /\ 1 + (z^2\ (p(1 - p))\ /\ e^2n) \quad (3.1)$$

Where s = sample size | n = population size | z = z-score | e = margin of error | p = standard deviation

A confidence level is defined as the statistical probability that the value of a parameter falls within a specified range. Therefore, a confidence level of N% means that it is N%

sure that the results contain in the true mean average of the designated population. Each confidence level is translated to a z-score. A z-score is a statistical method for rescaling the data that helps to draw comparisons easier (i.e) (90% = 1.645, 95% = 1.96, 99% = 2.58). The Confidence level is fixed, based on the understanding of the target population (Martin 2016). Based on the outcome of the qualitative survey, the confidence level and the margin of error was fixed as 90% and 10% respectively (Margin of error is the maximum acceptable difference in results between the population and sample). The quantitative survey was conducted for 12 months (January 2017 to December 2017). In total 4,676 invitations were sent out in which 403 responses were received which gives an overall response rate of 8.6%. Figure 3.8 shows the analysis of the responses received from different stakeholders.

Table 3.4 - Minimum Required Sample Size and Response rates

	Parents	**School**	**Operator**	**Driver**	**Council**
England	62	58	54	68	51
Scotland	5	6	7		4
Wales	1	4	6		3
Required Sample Total	68	68	67	68	58
Invitations Sent:	2500	500	1269	1269	407
Responses Received:	109 (4.3%)	73 (14.6%)	72 (5.6%)	80 (6.3%)	69 (16.9%)
Total:	403 (8.6%)				

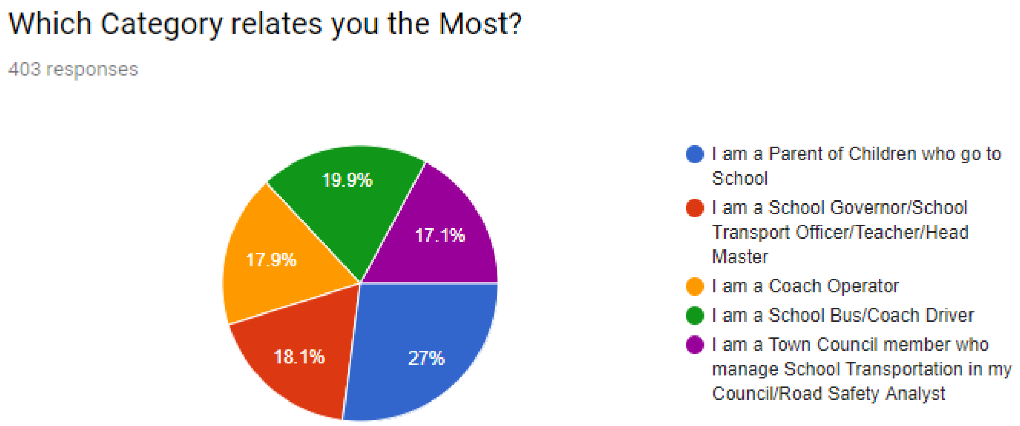


Figure 3.8 - Responses received from different stakeholders

3.6.2 Questionnaire

A Questionnaire for the quantitative survey (Appendix 3) was prepared based on the outcome of the qualitative survey. Once the questions were prepared, a pilot survey was conducted with two experienced stakeholders from each sector (Transport sector, Educational sector and social sector) to provide feedback on the suitability of the questions and their recommendations on the questionnaire structure were incorporated.

3.6.3 Survey Implementation

The updated questionnaire was uploaded to google forms, which provides a user-friendly interface for form creation and basic analytic tools. Research description was shown to the participant at the beginning of the survey.

3.6.4 Survey Analysis

Once the survey was over, the data from google forms was exported into the .xls format. As most of the questions were multiple choice based and had yes, no and may be type answers, it was simple to analyse the data as shown in Figure 3.9. The Cross-tabulation method was used to analyse the relationship between the stakeholders' answers (Hellevik 1988) as shown in Figure 3.10.

Parents: 109 total responses

Questions for Parents:

1. How do you ensure that your children are travelling safe on coach arranged by schools with respect to the safety compliance procedures of the coach operator, vehicle and the driver?
   a. I trust the school and believe that they will follow all the safety procedures to ensure the safety of children travelling in coaches. **(95 – 87.2%)**
   b. I trust the school but I also get involved with the coach booking process to make sure they book the safe coach operator. **(9 – 8.3%)**
   c. I am worried about the safety of my child travelling in a coach. So, I drive my child to the spot and drive back home. **(4 – 3.7%)**

Figure 3.9 - Quantitative data analysis

	PARENTS			SCHOOL HEAD MASTERS			OPERATORS			DRIVERS			TOWN COUNCIL		
REQUIREMENTS	YES	NO	MAYBE	YES	NO	MAYBE	YES	NO	MAYBE	YES	NO	MAYBE	YES	NO	MAYBE
GPS	99	1	9	68	0	3	47	8	17	61	6	13	51	4	12
BUS ESCORT	74	5	30	50	3	18	45	15	12	62	4	14	45	8	14
SCHOOLS SHOULD CHECK DRIVER AND VEHICLE STATUS	104	0	5										37	24	6
CCTV	58	13	38	43	7	21	55	6	9	69	1	10	60	2	5
MECHANISM TO CHECK DRIVER AND VEHICLE STATUS				45	5	21	42	10	19	48	13	18	40	14	12
DRIVER EDUCATION							46	16	10	58	7	13	53	7	7
LEGISLATION TO STOP PUPIL DISTURBING DRIVERS							53	7	11	61	6	13	16	32	19
GIVEN PROPER ROOM TO STAY										32	41	6			

Figure 3.10 - Cross tabulation analysis

3.7 Chapter Summary

To understand the safety of children travelling via coaches in the UK, a sequential exploratory mixed-method research design was implemented. This includes a qualitative survey followed by a quantitative survey. Luton Borough Council in East of England was selected as a study area for the qualitative survey and semi-structured interviews were used to collect the data. Based on the qualitative survey results, a quantitative survey conducted across the UK to test the results. The overall outcome of the survey is discussed in the chapter 4.

Chapter 4
Survey Results

4.1 Introduction

This chapter discusses the results of the qualitative survey followed by the quantitative survey. The survey results are compared with similar research published in the relevant literature. From the survey results, the significant issues and requirements of stakeholders are identified. The chapter concludes by a summary.

4.2 Qualitative Survey Results

The thematic analysis proposed by (Clarke and Braun 2013) was used to analyse the qualitative survey results. This resulted in the creation of two themes, "stakeholders' issues" and "stakeholders' requirements".

4.2.1 Safety Issues

Key issues expressed by most of the stakeholders were "*unawareness of the vehicle's and the driver's conditions*" throughout the journey. Parents pointed out that "*they trust the schools and the operators*" when asked about how they were sure about the safety of vehicles for the trips. Similarly, schools put their trust on the operators. But based on the traffic commissioner reports, a minimum of 2 to 3 operator's licenses are revoked every week in the UK due to operator's non-compliance (Commissioners 2017). Parents and schools are unaware of these statistics (Ramachandran, Sahandi, Prakoonwit, Khan, et al. 2017). "*Children's behaviour at bus stops and inside the bus*" is the second major issue reported by the stakeholders. Children who left unsupervised at bus stops and inside the bus may create unnecessary problems like bullying, fighting with each other, throwing items at each other when they are on the coach, etc. Most of the drivers reported that they were "*disturbed by children*" while driving the coach. In extreme cases, drivers had to stop the coach and resolve issues between the children before continuing their journey. School bus drivers are more likely to commit violations or errors than non-school bus drivers because of in-vehicle distractions from their young passengers (Yasmin et al. 2013). The next issue is "*lack of training of drivers*" in handling school children. This leads to "*driver's misbehaviour*" like yelling at children and getting tensed while driving puts the children at risk. Another issue is the "*use of inexperienced drivers*" who are responsible for most of the accidents. Required by law, drivers must have gone through a Disclosure and Barring Services (DBS) check before transporting school children. However, there is no law in respect of driver's experience regarding school transport. If drivers are DBS checked and hold a proper license, they can drive coaches for school trips.

Some drivers reported that "*vehicles being out of control*" is a common reason for accidents that had risen due to improper maintenance of coaches. Required by law, coach operators must carry out a daily walk around check, six-week maintenance check and yearly MOT for each coach. It is necessary to keep a coach fit for purpose and the frequency of checks varies depending upon the operator and the size of the fleet. If an operator is found failing to do any of these checks, it may lead to a 2-weeks suspension or license revoked. A typical reason for a 2-week suspension is the "*failure of drivers to carry out properly a daily walk around checks*".

"*Driver fatigue*" is another commonly reported reason for coach accidents. Allocating a driver who hasn't taken enough rest to a coach trip leads to driver fatigue, which puts children at risk. However, the "*real rest taken by the driver*" may not be known until the driver admits it.

It is mandatory for drivers to use a tachograph, a device that records the speed, distance travelled and driving hours of the driver. Required by law, drivers must strictly follow the driving hours. Based on the type of the trip legal driving hours may vary. The maximum legal driving hours allocated to a driver is 9 hours per day. Drivers must take a compulsory break after driving continuously for 4.5 hours. After completing 9 hours driving, drivers have to take a compulsory 11 hours break before driving the next day (DVSA 2016a). It is illegal to drive without a tachograph. Coach operators expressed during the interviews, "*driving hours violation*" is a serious issue with coach drivers, which must be addressed. In some accidents, coach drivers are not the one who commits mistakes. "*Behaviour of other drivers around the coach*" is also reported as one possible reason for coach accidents during the stakeholder interviews because sometimes, recklessness drivers around school coaches can lead to accidents. If a coach is carrying children, the coach should display the school bus sign on at the front and rear of the vehicle.

Some issues are specific to trip types. School trips by coaches may involve higher risks compared to home to school services. The major issue reported by the drivers during the interview is the issue with the long-haul trips is the "*21 hours double manned (drivers) trips*". If two drivers are assigned for a long trip, they can drive for 21 hours continuously with the same legal rest time (DVSA 2016a). The problem here is, when one driver is driving, the other one is expected to rest on the seat which may not be comfortable according to the drivers. In most cases, the second driver cannot sleep and end up driving without having an appropriate rest. Another issue mentioned by most of the drivers during the interview is the place where they stay during the trips. Drivers reported that they were "*not given proper accommodation*" during the trips. Sometimes the drivers are left without accommodation and expected them to sleep inside the coach. Even when accommodation is provided, it might be close to the area where students are staying and drivers are continuously disturbed by students whilst sleeping.

In respect of home to school transport, the major issue reported by the stakeholders was "*lateness*". Sometimes the parents fail to arrive at the right time, leaving children alone at the bus stops, which is worst during the winter months. In addition, sometimes coaches arrive late due to heavy traffic and parents make phone calls to know the location of the coach.

Table 4.1 and Figure 4.1 show the top 10 issues identified in the order of importance, expressed by all the stakeholders. Unawareness of the driver & coach conditions is the top issues identified among all the stakeholders. However, the order of importance may change depending on the type of stakeholder. For example, unawareness of driver's and coach's conditions are the top issue for parents and Headmasters, but for drivers', children's behaviour inside the bus is the primary issue.

Table 4.1 - Top 10 safety issues

No	Identified Issues	Trip Type
1	Unawareness of driver and coach conditions	Home to School Services (HSS) & Occasional Coach Hires (OCH)
2	Children behaviour (bus stop, inside the coach)	HSS&OCH
3	Delays of parents or drivers (lateness)	HSS
4	Inexperienced driver (driver error)	HSS&OCH

5	Driver become disturbed by pupils on the coach	HSS&OCH
6	Vehicle out of control (vehicle error)	HSS&OCH
7	Driver fatigue	HSS&OCH
8	Other vehicles behaviour around the coach (external factors)	HSS&OCH
9	21 hours double team journey	OCH
10	Driving hours violation	HSS&OCH

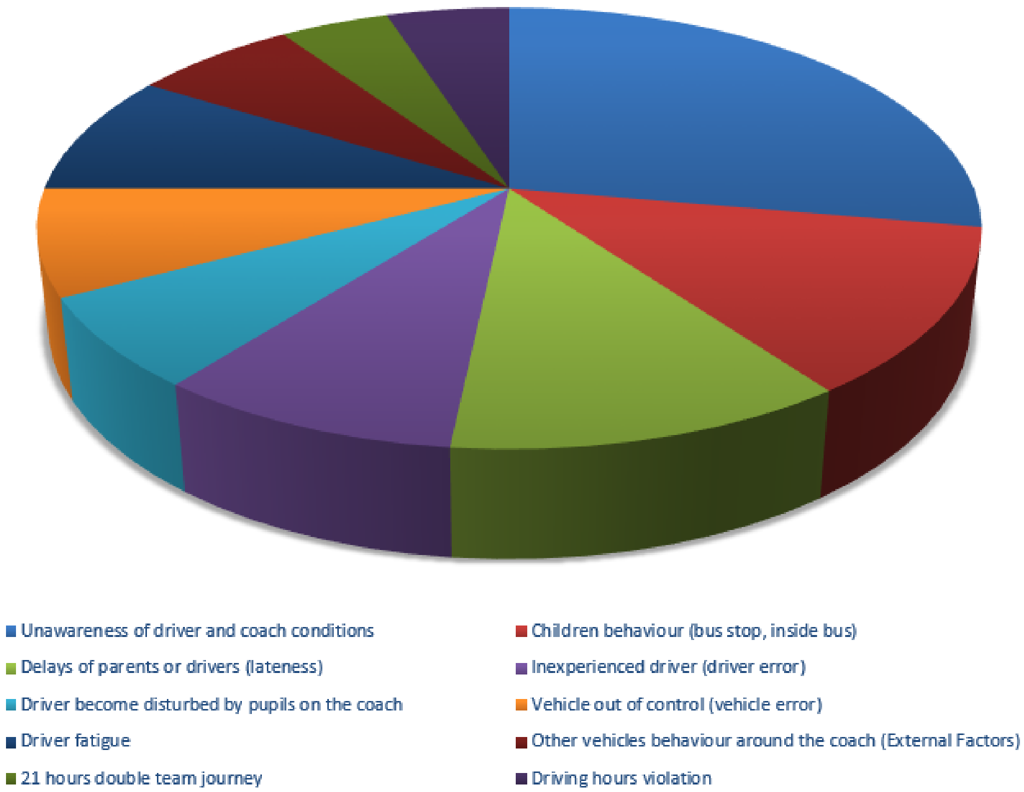


Figure 4.1 - Top 10 safety issues in school transport using private coach hires

Figures 4.2 to 4.7 show the significance of the issues as expressed by the stakeholders. Coach operator's order-of importance of issues related to the things which affect the service they provide. The first 4 issues in Figure 4.2 relate to children, parents and schools and the subsequent issues concern drivers. Figure 4.3 shows the top 10 issues relating to coach drivers. Most of them relate to the involvement of drivers with children. Other issues like difficulties in 21 hours double team journey and night stay during trips only relates to drivers.

Figure 4.4 and 4.5 show the top issues expressed by Headmasters and parents which concern children safety. Figure 4.6 and 4.7 show the top issues of road safety, as indicated by analysts and local authorities during the interviews.

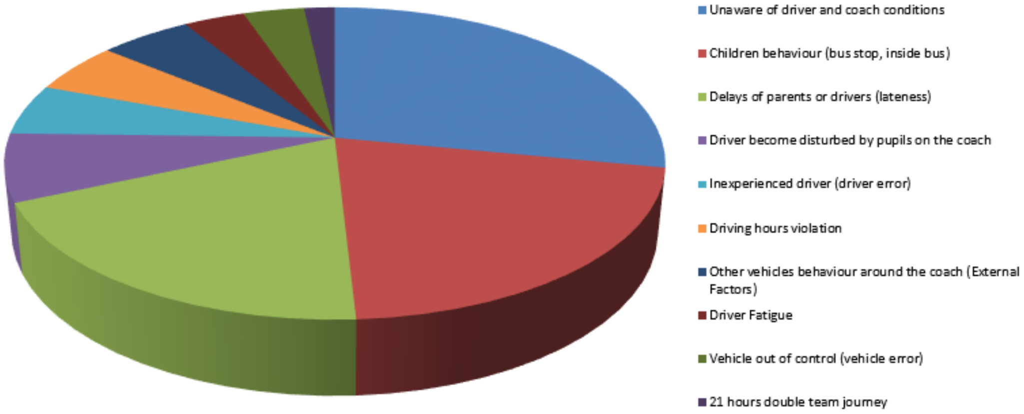


Figure 4.2 - Top 10 issues of coach operators

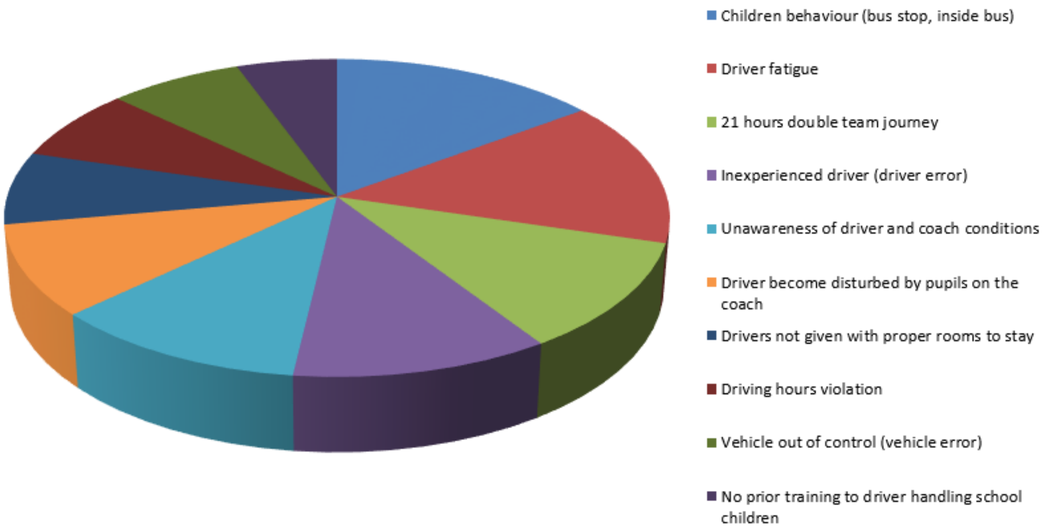


Figure 4.3 - Top 10 issues of coach drivers

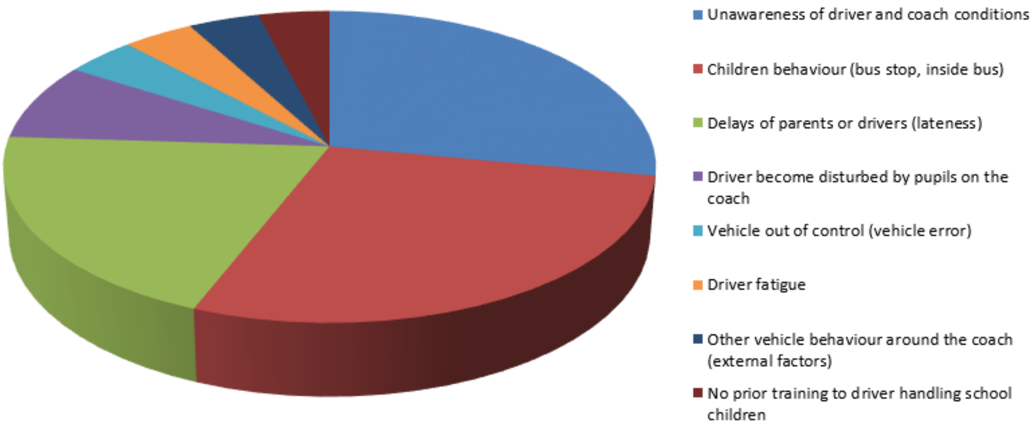


Figure 4.4 - Top 8 issues of Headmasters

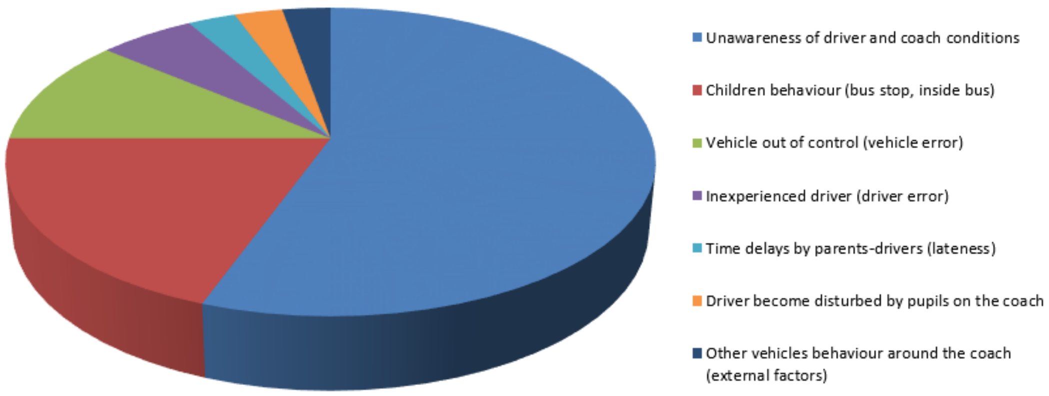


Figure 4.5 - Top 7 issues of parents

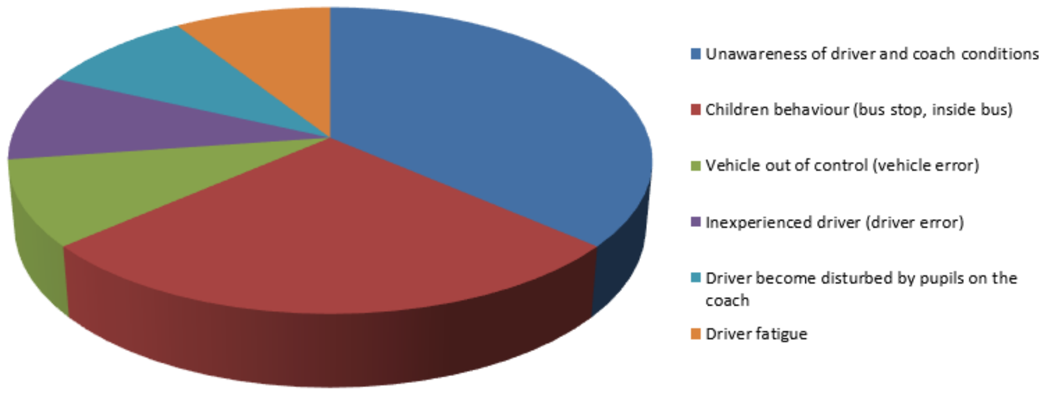


Figure 4.6 - Top 6 issues of road safety analysts

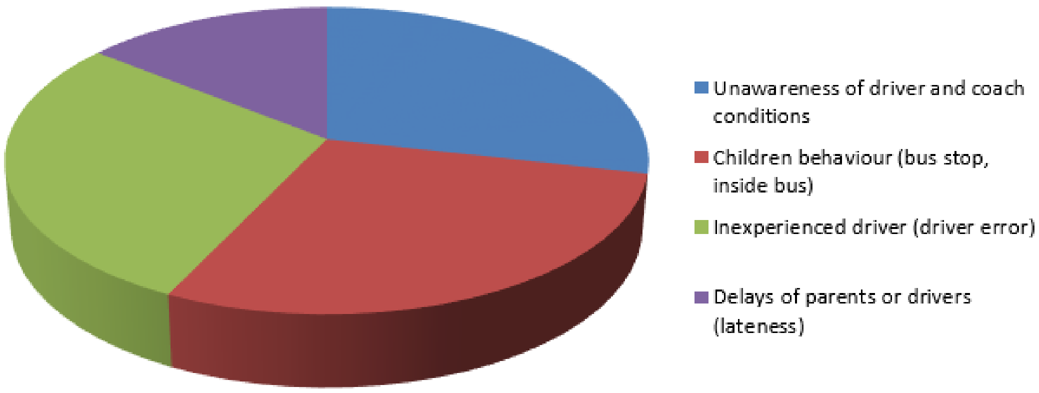


Figure 4.7 - Top 4 issues of Town Council Transport Officers

Comparing the top issues of all the stakeholders, it is evident that unawareness of drivers and vehicle conditions is one of the major issues identified. In the survey, coach operators have admitted that schools or parents never inquired about the vehicle's or driver's conditions in their many years of experience. Not verifying the driver and vehicle conditions puts the children at risk. In Table 4.1, issues number 1 – Unawareness of driver and coach conditions, 4 – Inexperienced driver (driver error), 6 – Vehicle out of control (vehicle error) and 10 – Driving hours violation are most significant which should be tested across the UK to check the presence of these issues nationwide along with the other issues. The existing work (Anund et al. 2014, Kotoula et al. 2017b) to identify safety issues in coach-based school transport di not address the top issues identified through this study.

4.2.2 Stakeholder Requirements

The foremost requirement expressed by most of the stakeholders is the "*need for bus escorts*". Bus escorts are the people who take care of the children during the journey. They help to avoid problems like bullying, students running around, not wearing seatbelts etc. "*Supervising children at bus stops*" is expressed by interviewees as a way to avoid problems faced by children before they enter the coach. Having a bus escort may increase operational costs. So, there is a financial difficulty for operators in employing bus escorts. The next major requirement to content is the ability to know the location of vehicles ("*vehicle tracking*"). If a coach is late because of traffic or any other reason, worried parents call the coach driver or operator to find out about the location of the coach. So, vehicle tracking is now an essential requirement for coaches which are used for school transport. Though vehicle tracking systems are already available, the cost of installation of tracking systems is still high.

The next main requirement expressed by most of the interviewees is the "*mechanism to know the driver or vehicle status*". As mentioned earlier, coaches for school journeys are ordered based on "*trust*". But most of the stakeholders (parents and Headmasters) would like to know the status of the vehicle and driver before the commencement of journeys. "*CCTV Cameras*" present in most of the modern coaches in which their recordings become proof for any safety-related issues. Stakeholders indicated that having a CCTV camera will be an alternate option for bus escorts because; most of the time students remain calm because of the fear of being recorded. The recordings are protected by the Data Protection Act 1998 in which only the authorities (i.e) school Headmasters and coach operators are allowed to view it.

Apart from coach operators and drivers, all other stakeholders expect "*schools to check the vehicle's and driver's condition*" before the journey, but most schools fail to do so. Many interviewees requested for "*proper driver and passenger education*" from the government which helps the drivers and children to behave during the school journey. Some drivers expressed during the interviews that sometimes, over speeding does happen, even having strict "*speed limits*" set by the government as well as the operators. So, there is a need to make sure that the speed limits are always adhered to by drivers. Almost all the coach operators argued that there is a "*need to avoid roads with tight bends*". Currently, the routes are analysed using Google maps and the drivers requested if there is a way to know about narrow road or sharp bends, it will be more effective to plan the routes for schools' journeys.

Parents would like operators and schools to select "*brighter bus stops*" and "*a bus stop which is not on a busy road*". These two requirements regarding bus stop selection are important because during winter months sun will be very low and it gets dark very early. So, selecting brighter bus stops is an important requirement. Regarding the routes which are selected for school trips and home to school journeys, coach operators prefer to select motorways. "*Preferring motorways*" during school journey is important to avoid time delays and faster arrival to the destination. One of the common reasons for coach accidents is when the driver is distracted by pupils on the coach. There is no legislation which stops people from disturbing driver while driving. For example, during journey Headmasters had asked a driver to change the music which actually distracts the driver from driving. Coach operators and drivers believe there is a "*need for legislation to stop people on coaches distracting drivers*" during journeys.

Apart from vehicle tracking, "*student tracking*" is one of the requirements. Various student tracking systems are available on the market but as the vehicle tracking system, it has a high cost for deploying which makes coach operators to contemplate about implementing it. There is also a requirement for safe and efficient route planning systems which lets schools and coach operators plan the "*shortest possible route*". This was one of the issues raised by the interviewees. "*safe driver*" means safe travel. Driver actions are contributing factors in more than 90% of road crashes (Yasmin et al. 2014).

Drivers agreed that to "*avoid traffic*", often they have to take diversions during trips to reach the destination on time. So, a system to plan safe routes in case of traffic or emergency is one of the requirements of coach drivers.

Table 4.2 and Figure 4.8 show the top 10 requirements which are identified in the order of priority by the interviewees. Need for bus escorts, vehicle tracking and the mechanism to provide information about driver's and vehicle's status are amongst the top 3. However, in respect of priority, there were different views amongst the interviewees.

Table 4.2 - Top 10 Requirements of Stakeholders

No	Requirement	Trip Type
1	Bus escorts	HSS&OCH
2	Vehicle tracking	HSS&OCH
3	Information about driver's and coach's status	HSS&OCH
4	Supervise student at bus stops	HSS
5	CCTV Cameras	HSS&OCH
6	Schools need to check the vehicle's and the driver's documents for safety reasons	HSS&OCH
7	Requirement for driver - passenger education	HSS&OCH
8	Avoid narrow roads and sharp bends	HSS&OCH
9	Use routes with brighter bus stops	HSS
10	Bus drivers prefer motorways	HSS&OCH

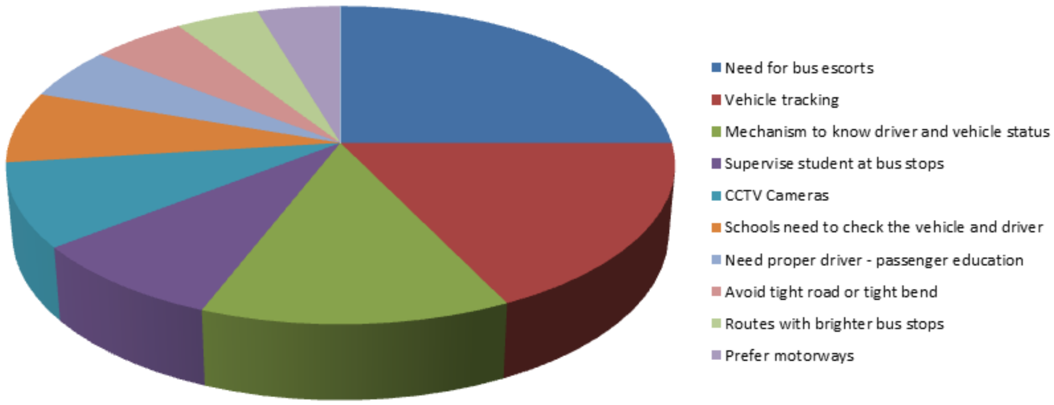


Figure 4.8 - Top 10 requirements in school transport when using private coach hire

Figures 4.9 to 4.14 show the individual requirements as mentioned by the stakeholders to improve the safety of children in coach-based school transport. Figure 4.9 shows the top 10 requirements by the coach operators interviewed. Similar to the issues mentioned in the previous section, coach operators are more concerned about the service they provide. Figure 4.10 shows the top 10 requirements of coach drivers. Coach drivers are more concerned about their distraction in the coach by the pupils while driving. Figure 4.11 and 4.14 show the top 10 and top 4 requirements of the parents and Headmasters. The major requirement for parents is to know that their children are travelling safe and where the coach currently is. To make sure that the children are travelling safe, tracking systems and mechanism to know driver and vehicle status are required. Figure 4.12 and 4.13 show the top 5 requirements of road safety analysts and town council transport officers. Most of the requirements are similar and both the stakeholders are concerned more about the children safety.

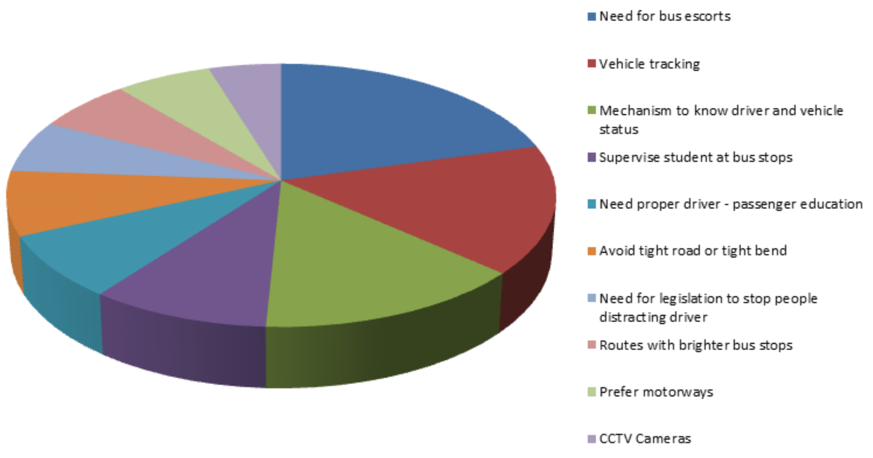


Figure 4.9 - Top 10 requirements of coach operators

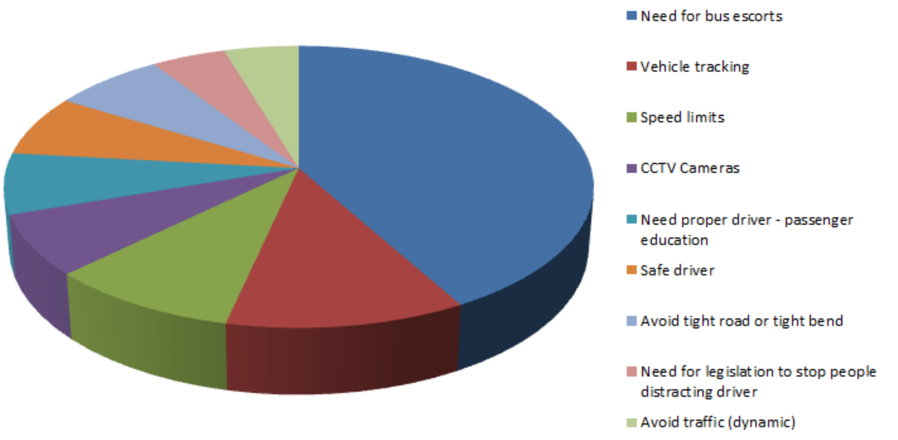


Figure 4.10 - Top 10 requirements of coach drivers

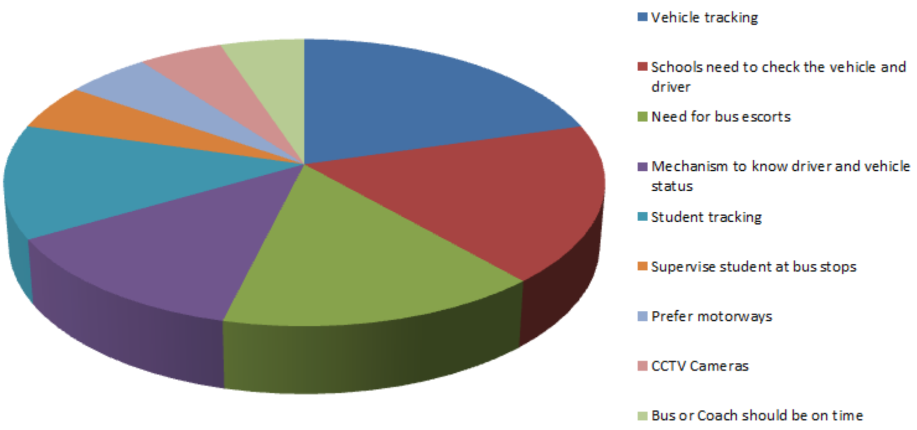


Figure 4.11 - Top 10 requirements of parents

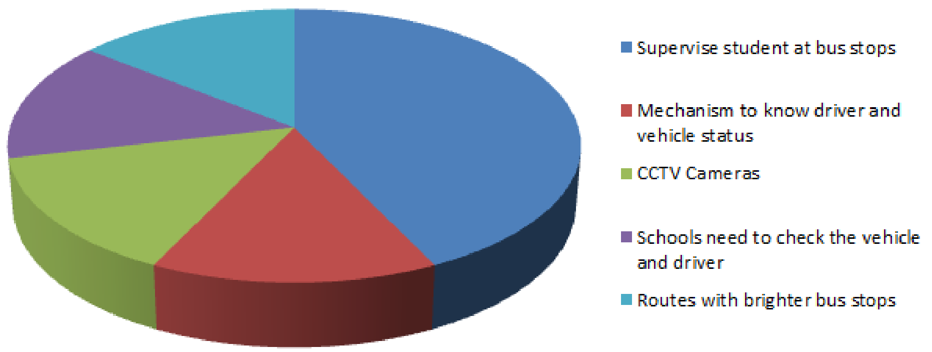


Figure 4.12 - Top 5 requirements of road safety analysts

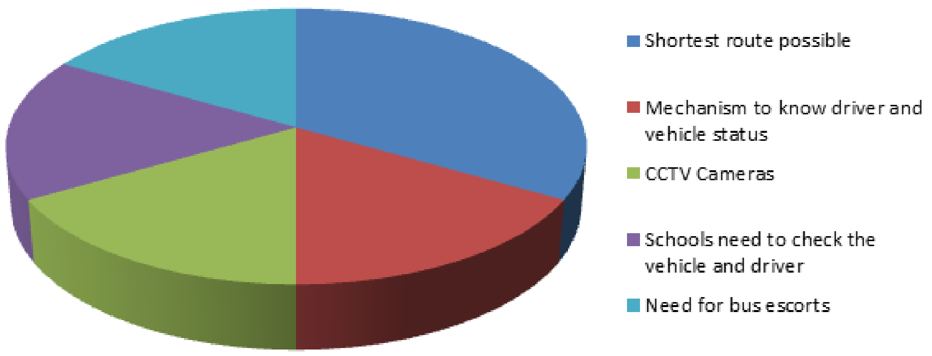


Figure 4.13 - Top 5 requirements of town council transport officers

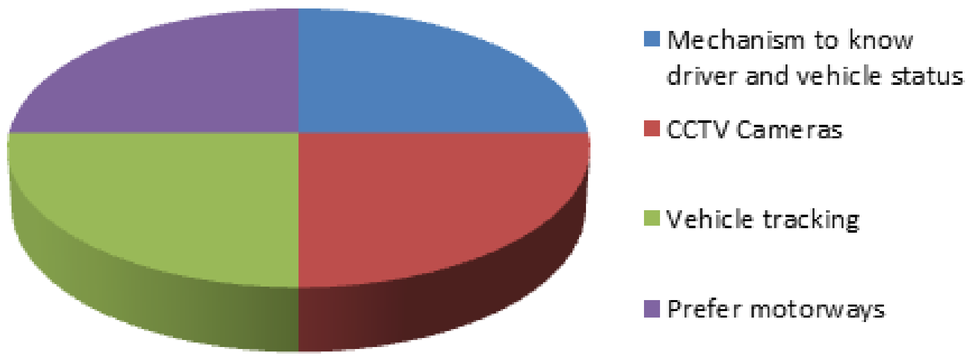


Figure 4.14 - Top 4 requirements of Headmasters

By analysing the top requirements of the stakeholders listed in table 4.2, the most significant ones identified are requirement number 3 (Information about driver's and vehicle status) and 6 (Schools need to check the vehicle's and the driver's documents for safety reasons). The research by Shaaban et al. (2013), Anund et al. (2014), Zambada et al. (2015), Hemalatha et al. (2017) to identify the requirements of stakeholders in coach-based school transport did not address the significant issues identified through this survey. Thus, the existing literature confirms the novelty of the requirements identified in this survey.

4.2.3 Limitations of the Survey

This qualitative survey has few limitations. Luton Borough Council in East of England is selected as the study area and the results are based on this area. It is important to test the existence of the identified issues and requirements all over the UK. The coach operators who participated were properly complying with the government guidelines. However, those operators whose licenses were revoked did not participate in this survey. School children were not included in this survey as the intention was to identify the higher-level problems that arise due to operator non-compliance and other safety issues in coach-based school transport. Future research could, include children in their survey.

4.3 Quantitative Survey Results

The objective of this quantitative survey was to extend the research to a broader geographical area further investigating the safety issues, which were emerged from the qualitative survey, conducted in Luton Borough Council.

4.3.1 Safety Issues

From Section 2.7.2, we understood that contributory factors for 49% of the coach accidents were only reported to the government and recorded. The remaining 51% of the contributory factors for coach accidents were unknown or not reported. Therefore, during the two surveys, the stakeholders were asked for their views on the cause for coach accidents when carrying children. Most of the replies related the cause to vehicle errors and driver errors for coach accidents. This correlates with the information that coach exist in the DfT-Ras database (DfT - Ras50005 2017). Table 4.3 and Figure 4.15 show the contributory factors for coach accidents as mentioned by the stakeholders of coach-based school transport. The table indicates the number of responses by the stakeholders.

Table 4.3 - Possible contributory factors for coach accidents – number of responses by stakeholders

Issues	**Parents**	**School Head masters**	**Operators**	**Drivers**	**Town Council**	**Total number of responses**
Vehicle error	77	55	32	39	31	234
Driver error	55	41	38	42	32	208
Inexperienced driver	37	26	22	18	18	121
Driver got disturbed by the pupils	16	14	22	25	17	94
Other vehicles around the coach	26	27	26	26	43	148
21 hours journey	-	-	26	24	8	58

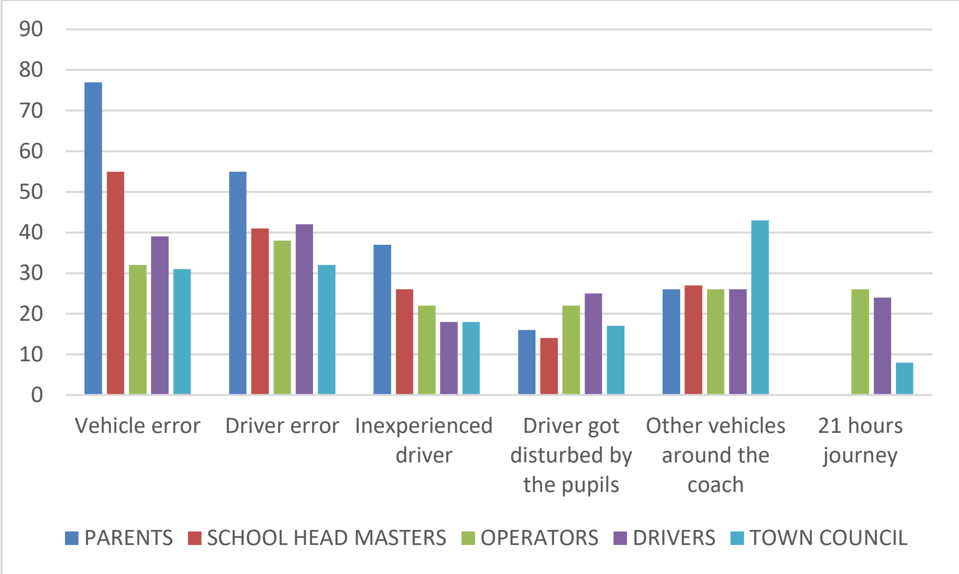


Figure 4.15 - Possible contributory factors for coach accidents (stakeholder responses)

4.3.2 Stakeholder Requirements

Each stakeholder has different requirements with respect to coach-based school transport. Table 4.4 shows the number of stakeholders' responses and Table 4.5 the top requirements by the stakeholders respectively. The topmost requirement identified is "*GPS tracking*" of coaches carrying schoolchildren. In terms of order of priority, in this survey, GPS tracking topped the list, compared to the limited qualitative survey, which appeared to be a lower priority. This reflects the need for school vehicle tracking across the UK. Across the stakeholders, parents were very keen on the utilisation of GPS tracking. Parents and town councils urged schools to check vehicles' and drivers' status before commencing the journey. 60% of the stakeholders answered "yes" and 10% of the stakeholders answered "maybe" when they were asked, "do you need an effective mechanism to check the driver and vehicle status before commencing a school journey". This reflects the interest of stakeholders wanting to know the quality of service they receive to ensure that schoolchildren are travelling safely on coaches. Stakeholders also answered "yes" to when they were asked about the use of CCTV to record the pupils during the journey. Operators, drivers and town councils requested for driver and passenger education before commencing the school trips for the first time. Operators and drivers requested a legislation to stop pupils from disturbing the drivers during a journey. However, the majority of the councils disagreed for the need for legislation. They believe bus escorts or teachers in the vehicles during trips can supervise students. During the qualitative survey, drivers mentioned that they are not given proper room to stay during the school trips. To check this, drivers around the UK were queried about this. More than 50% of the drivers expressed that they are not given proper room to stay during the school trips which affects their sleep resulting in poor driving. Table, 4.4 and 4.5 indicate the number of responses by stakeholders. In Table 4.5, yes, no and maybe Indicates the total number of responses by the stakeholders from Table 4.4

Table 4.4 - Stakeholder requirements

	Parents			**School Headmasters**			**Operators**			**Drivers**			**Town Council**		
Requirements	yes	no	maybe	yes	no	maybe	yes	no	maybe	yes	no	maybe	yes	no	maybe
GPS Tracking	99	1	9	68	0	3	47	8	17	61	6	13	51	4	12
Bus escort	74	5	30	50	3	18	45	15	12	62	4	14	45	8	14
Schools should check driver and vehicle status	104	0	5										37	24	6
CCTV	58	13	38	43	7	21	55	6	9	69	1	10	60	2	5
Mechanism to check driver and vehicle status				45	5	21	42	10	19	48	13	18	40	14	12
Driver education							46	16	10	58	7	13	53	7	7
Legislation to stop pupil from disturbing drivers							53	7	11	61	6	13	16	32	19
Drivers are not given proper room to stay during the school trips										32	41	6			

Table 4.5 Top stakeholder requirements

Requirements	**yes**	**no**	**maybe**
GPS Tracking	326	19	54
Bus escort	276	35	88
Schools should check driver and vehicle status	141	24	11
CCTV	285	29	83
Mechanism to check driver and vehicle status	175	42	70
Driver education	157	30	30
Legislation to stop pupil from disturbing drivers	130	45	43
Drivers are not given proper rooms to stay during the school trips	32	41	6

4.4 Empirical Findings

Parents were queried, how they ensure that their children are travelling safely with respect to the safety compliance procedures of coach operators, vehicle and driver, on coaches arranged by schools. In response, 87.2% of the parents answered that they trust the school and believe that they will follow all the safety procedures to ensure the safety of children. Further, 8.3% of the parents indicated that they trust the school, but also became involved with the coach booking process to ensure the schoolbook for safe coach operators. Remaining parents expressed their concerns about the safety of their children travelling on coaches as shown in Figure 4.16. (Full version of the responses can be found in Annexure 6 and 7). These show that the majority of the parents across the UK are not aware of the safety level of the hired coaches that their children are travelling in and believe that the schools take care of the safety of their children. Very few parents are involved in arranging coaches for school trips. To those who were involved in arranging coaches, they were further questioned, "how do they select their coach operators for a journey?" In total, 50% of the parents responded that they conduct an internet search to find operators with good reviews and low prices. Further, 30% of them indicated that they request recommendations from their councils. Further, 20% of them responded that they use experienced operators that they have been using for a long time and had no issues with them. Interestingly, 90% of the parents indicated that they trust coach operators and they do not check the operators for compliant with the government safety regulations. This shows that the parents who involved in booking coaches for school trips were also unaware of the coaches' conditions and drivers' safety compliance history.

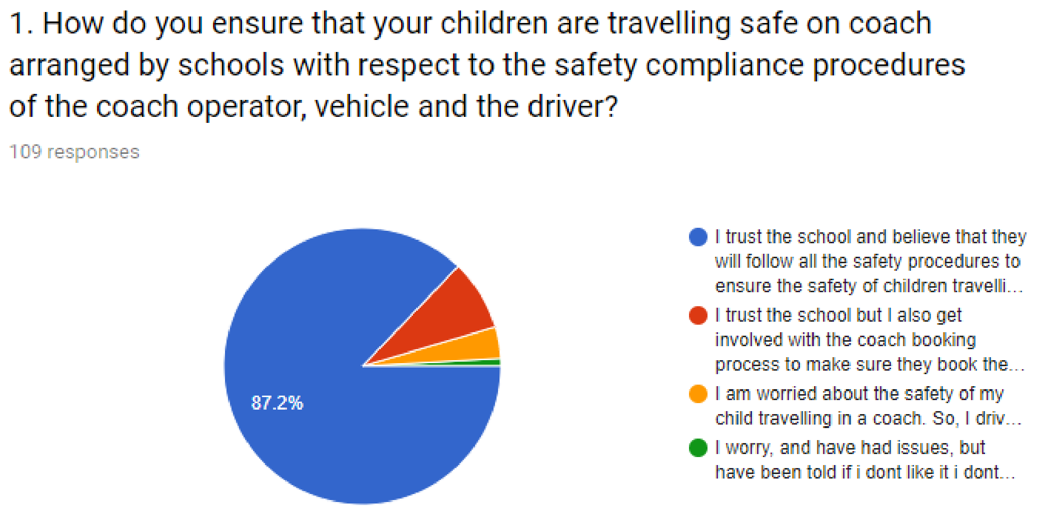


Figure 4.16 - Parents responses

The school Headmasters were asked, how they select their coach operator for a journey (as shown in the Figure 4.17)? In total, 47.9% of them responded, by stating that they use experienced operators that they have been using for a long time and never had any issues with them. A further 31% of the Headmasters indicated that they sought recommendations from their County Councils for selecting coach operators. Finally, 9.9% of the Headmasters indicated that they conduct an internet search to find operators with good reviews and low prices. These show that there are no pre-check safety criteria applied for the identification of safe coach operators apart from seeking suggestions from the local Council (Department for Education 2014).

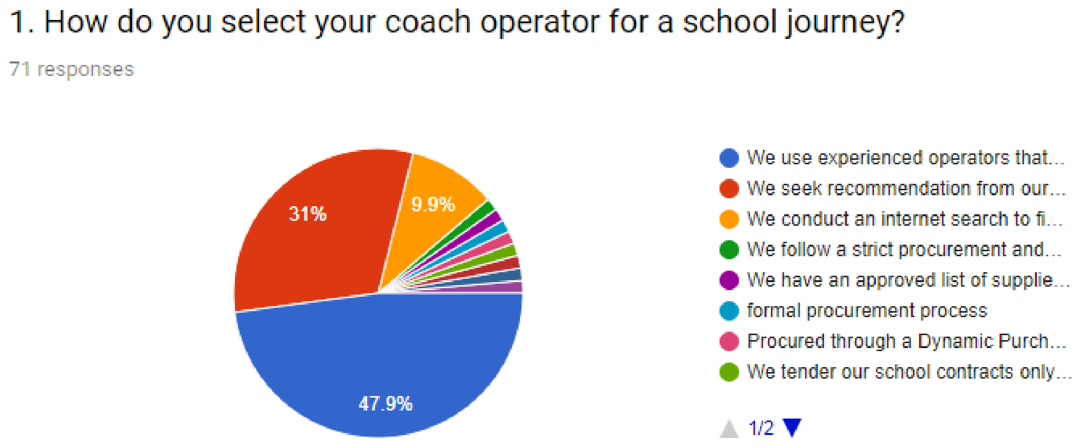


Figure 4.17 – Responses of the Headmasters to the first question

Further, to check, how schools validate the safety of the coaches and drivers that they are choosing for school trips, they were asked, "how do you ensure that the coach operator is compliant with the government safety regulations?" In total 87.3% of the Headmasters indicated that they do not perform checks on operators in respect of their compliance with the government safety regulations". However, 5.6% indicated that they check the operators' OCRS scores and driver(s) license points" as shown in Figure 4.18. That 5.6 % were further questioned, "how do they ensure that the details provided by the operator are correct?" In response, 91.4% of the Headmasters indicated that they trust the operator and accept the information that they provide. Only 2.9% of the Headmasters answered that they cross check with the DVLA before booking a coach. This clearly shows that schools are not aware of the safety status of coach operators, their coaches and drivers.

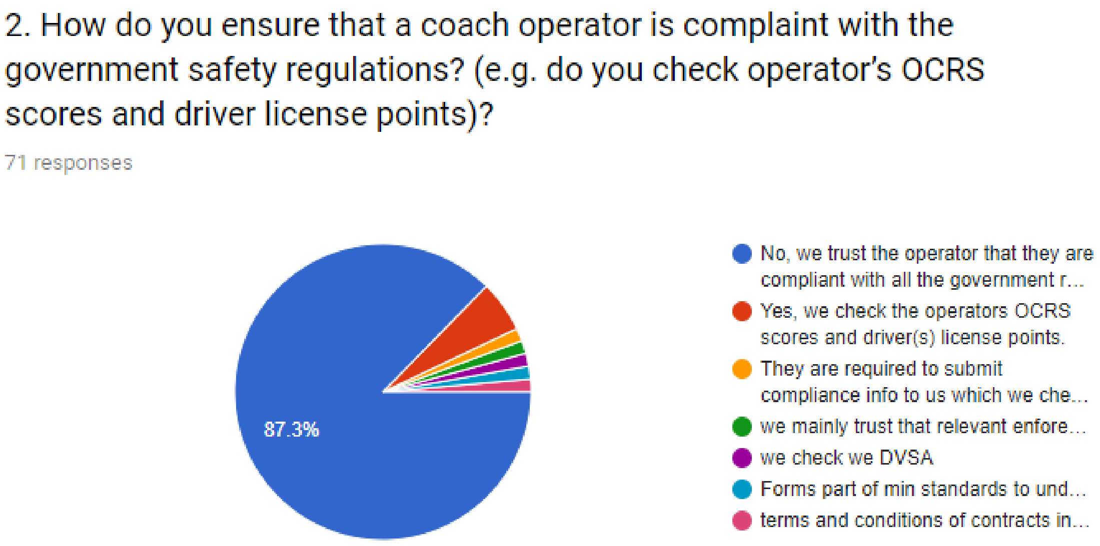


Figure 4.18 - Response of the Headmaster to the second question

Further, coach operators and drivers were asked, "in your experience in coach industry, have you ever been asked by schools to provide information on your OCRS scores, (Operator Compliance Risk Score)?". In total 87.3% coach operators and 83.5% of drivers indicated, "No, they had never been asked". 11.3% coach operators and 15.2% coach drivers indicated they been rarely asked. Only, 1.4% of coach operators and 1.3% of drivers answered, "Yes, they had been asked for it all the time. Figure 4.19 and Figure 4.20 show the coach operator and driver responses. The majority of the stakeholders in the coach industry confirmed that schools never enquired about their safety levels. This further compliments the responses of the parents and other stakeholders.

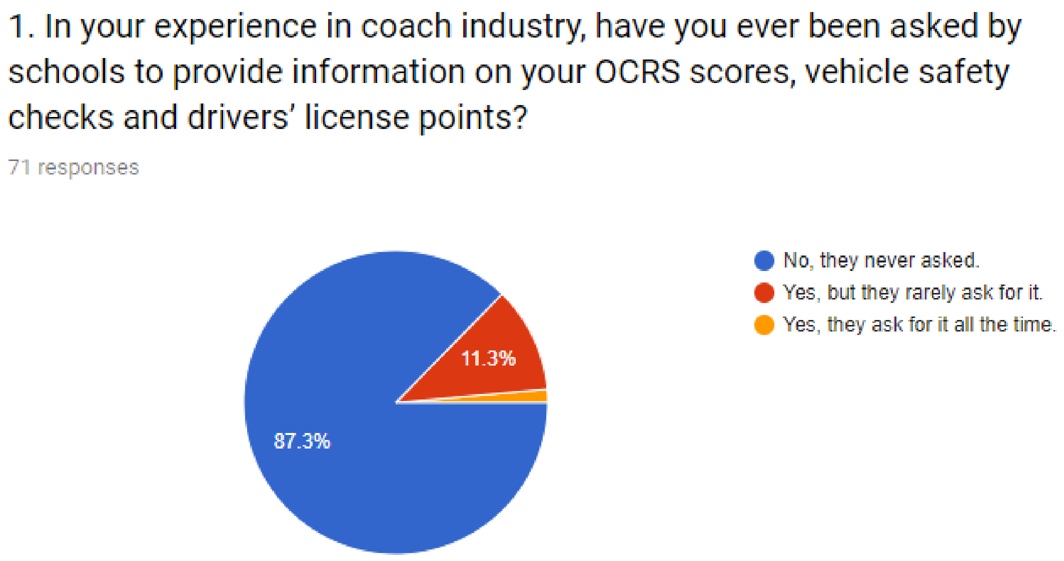


Figure 4.19 - Questions and the response of coach operators

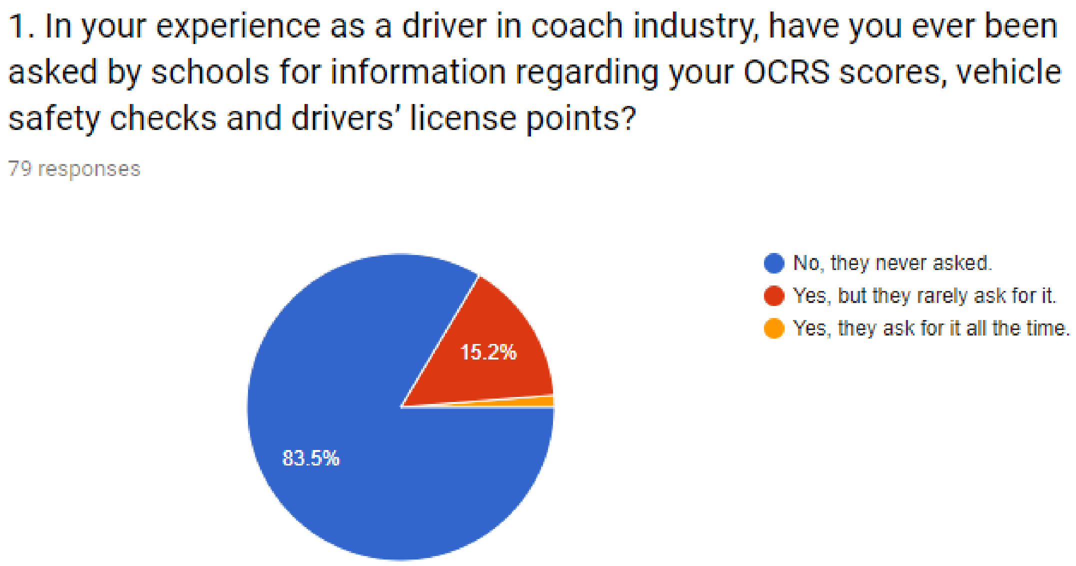


Figure 4.20 – Question and response of coach drivers

However, to further verify this, town council transport officers were questioned, "do you think schools check coach operator's OCRS scores, vehicle safety checks and drivers' license points before their children commencing a coach journey?". In total 63.6% of county councils responded, "No they don't". A further 10.6% answered "yes, but they rarely check it and 4.5% of them replied, “yes, they check it all the time”. This confirms that most of the schools do not check the safety level of the coaches selected for school trips. In response to the question “do you think parents check coach operators’ OCRS scores, vehicle safety checks and drivers’ license points before the children commencing a coach journey?”. In total 85.1% of the Council said “No, they don’t” and 1.5% of them said, “Yes, but they rarely check it”. Figure 4.21 and 4.22 shows the town councils’ responses. These results confirm that an inappropriate approach in booking (i.e.) booking coaches without checking the compliance of coach companies and the knowledge gap clearly exists between the parents, schools and coach operators. As it was mentioned in Section 4.3, the results prove deficiencies in the practice across the UK and the knowledge gap among the stakholders identified through this survey. This issue has not been addressed in the literature (Aigner-Breuss et al. 2010, Anund et al. 2011, 2014, Kotoula et al. 2017a). Full detailed analysis of the survey are provided in Section 4.5.

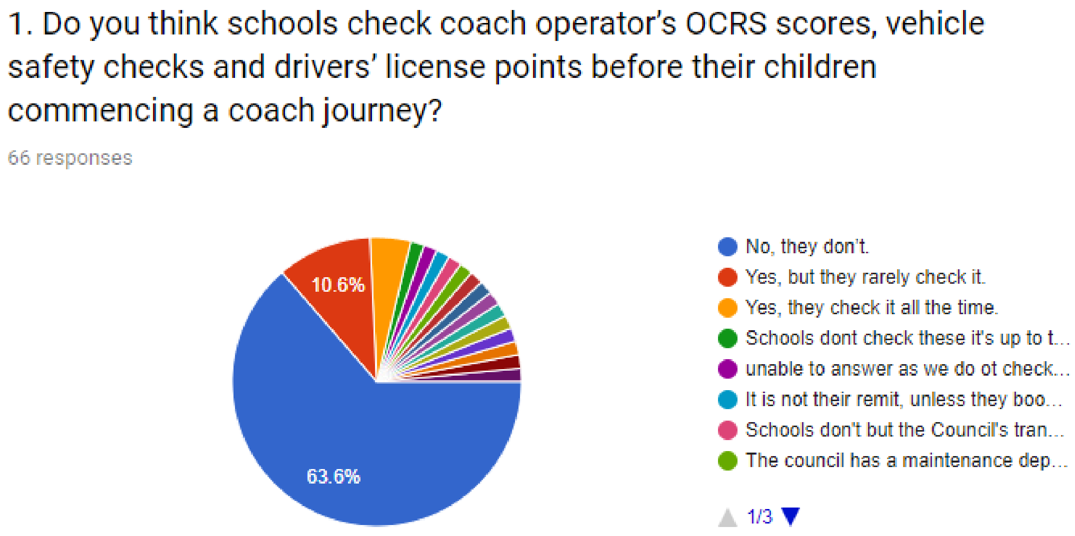


Figure 4.21 - Town Councils response 1

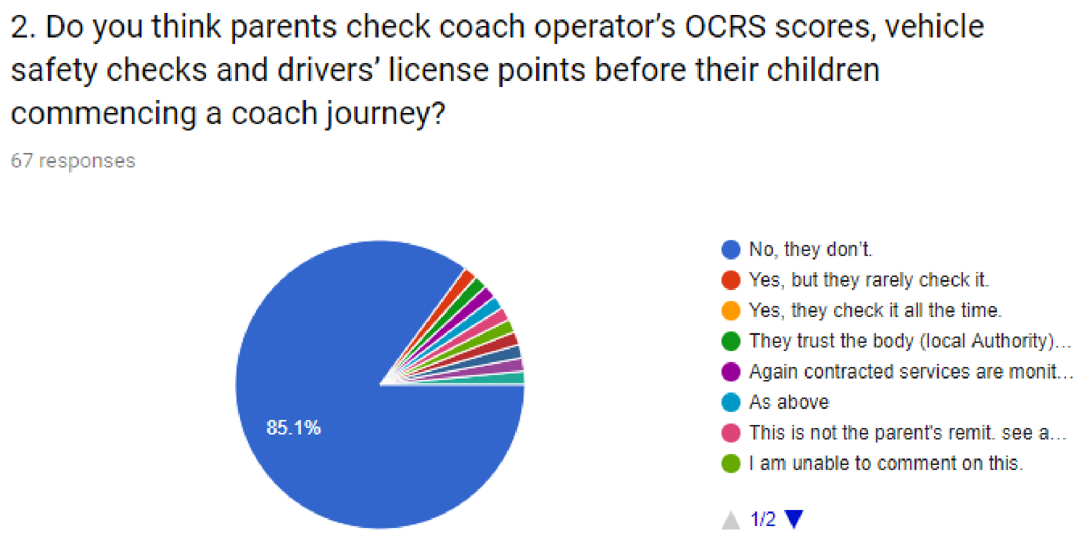


Figure 4.22 - Town Councils response 2

4.5 Results Interpretation

When planning any activities, schools are required to demonstrate that they have conducted risk assessments for a daily home to school transport or the occasional trips which are considered as high-risk. This is even more crucial if the transport is made through private coach hires where a third-party operator is involved who is not operating under the school management. Normally schools complete their risk assessments paperwork before each trip. However, this does not stop coach operators from using non-roadworthy vehicles or unsafe drivers who are not fit to work or improperly trained. The qualitative survey analysis showed the critical issues present in the coach-based school transport. It also showed the critical knowledge gap present between the stakeholders. However, to test these results all over the UK, a quantitative survey was conducted. Results of the quantitative survey proved the existence of the top significant issues and requirements identified through the qualitative survey. Previous efforts to identify the safety-related issues (Anund et al. 2014, Kotoula et al. 2017a) and requirements (Aigner-Breuss et al. 2010, Anna et al. 2012) with coach-based school transport did not address the high significant issues (No. 1, 4 and 6 from Table 4.1) and requirements (No. 3 and 6 from Table 4.2) identified through this study. The less significant issues (No. 2, 3, 5, 7, 8, 9 and 10 from Table 4.1) and requirements (No. 1, 2, 4, 5, 7, 8, 9 and 10) proved that the issues and requirements of stakeholders in the UK is similar to the issues and requirements in Europe addressed in the existing literature (Anund et al. 2010, 2014, Ipingbemi and Aiworo 2013b, Harrison et al. 2014, Beck and Nguyen 2017b, Caceres et al. 2017, Hemalatha et al. 2017, Kotoula et al. 2017a, Villa-González et al. 2018, Miranda et al. 2018, Takalikar et al. 2018). Therefore, the significant findings of this survey i.e. "unawareness of the driver and vehicle condition by parents and schools" are unique and novel.

The contributory factors for coach accidents mentioned by the stakeholders match the contributory factors reported by the government. The surveys also show it is unlikely that schools would check the coach operator's safety records for compliance with the government's procedures and regulations. With 48,000+ school trips made every year, it is important that schools are able to access and select the right coach operator their trips. However, it seems that schools do not have access to relevant databases or do not have sufficient knowledge about the coach industry. There is a misconception amongst the schools that if the coach operator has a licence to operate, they fully comply with all the government regulations. However, in reality, coach operators are not compliant all the time and the traffic commissioners' reports confirm this. It is evident that there is a serious knowledge gap present between the stakeholders. This should be given immediate attention before children lives are put at risk. We tried to address the significant issues and requirements identified through the surveys through our safety solution which is explained in the next section.

4.6 Standards and Solutions

The issue for schools is that without specialist knowledge it is very difficult to know which is which. The ability to make an informed choice is vital. It is highly unlikely any teacher, governor or parent will be technically able to properly assess the safety credentials of a commercial coach fleet operation. For those who make the decision on price, the cheapest price quotation (quote) from operators may not always be the safest quote but it may be if certain criteria are met. Consider how this process could be improved if schools selected coach operators who were able to demonstrate minimum requirements in terms of safety and perhaps industry good practice through regular operator validation. By sourcing coach transport from fleet operators that are validated to a recognised industry standard helps remove the need for technical capability and provides a level of assurance. There are three key areas, which should be used to identify a safe fleet operator:

a) Safer operator: meeting the standards of the DVSA in terms of fleet operation.

b) Safer coaches: ensuring vehicles are roadworthy and safety checks are carried out regularly to the DVSA standards.

c) Safer drivers: confirming drivers are medically fit, within legal driving hours, are trained on road risk and their driving licences checked through DVLA.

A safety transport framework is proposed which validates a coach operator by analysing the above three key areas. The framework will not only validate the coach operators, but also provide recommendations to improve their fleet safety, based on analysing their past incidents/records. The framework is discussed in detail in Chapter 5.

4.6.1 Quotation Process

Quotation is the process of obtaining prices from coach operators for a particular school journey between two geographical locations. Headmaster or an event-coordinator in school carries out the safety assessment for a school trip and then selects an appropriate coach operator to provide the service (sometimes parents recommend coach operators to the Headmasters). Many coach operators in the UK provide coach services for school trips. To select a coach operator, a headmaster/event-coordinator (customer) normally provides details of a school journey to several coach operators (brokers) to obtain quotations. A quotation normally provides a list of coaches with corresponding prices for the journey. The prices vary depending on the type of coach, number of passengers and distance between source and destination. If the customer is happy with the quotation, a booking is made for the coach. Figure 4.23 shows the existing quotation process where no validation of coach operators involved.

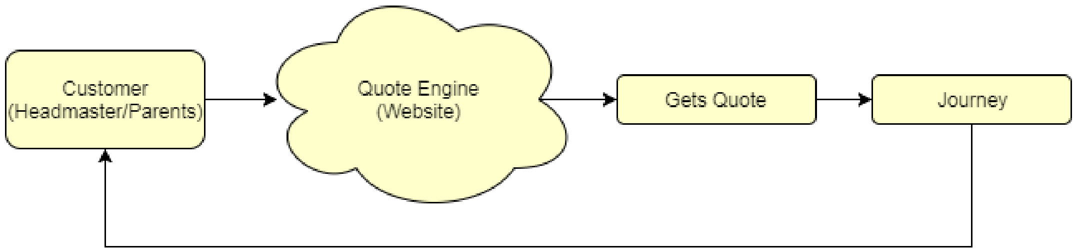


Figure 4.23 - Existing quotation process

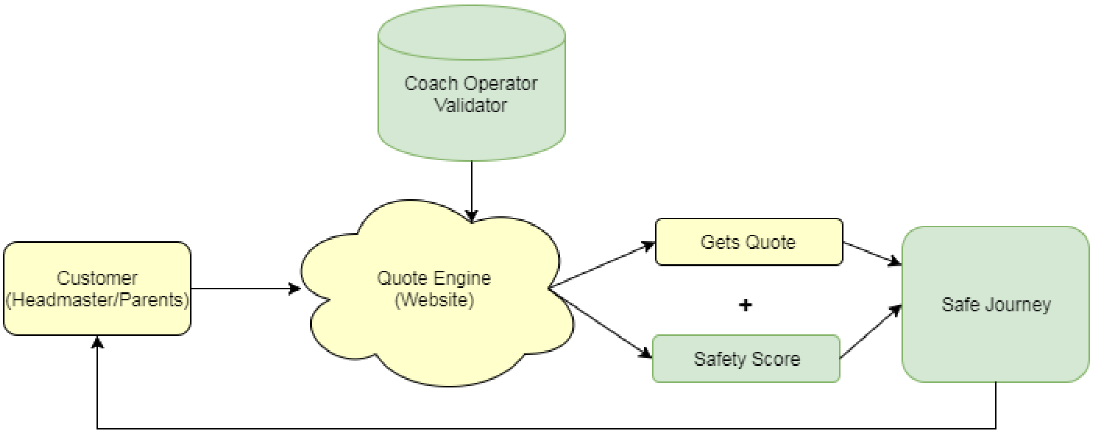


Figure 4.24 - Quotation process with coach operator validation

Figure 4.24 shows the quotation process that employs our proposed safety framework, which introduces a coach operator validator that connects with the existing quotation system. When customers try to get a quote, coach prices along with their safety score will be displayed. This helps the customers to make an informed decision thereby reducing the risks of selecting an operator who is non-compliant with the government safety guidelines. The framework can also act as a stand-alone system for validation of a coach operator without the quotation engine and to provide intelligent safety recommendations for coach operators. Next chapter discusses the safety transport framework in detail.

4.7 Chapter Summary

This chapter presented the results of a sequential mixed method research design. Significant issues of coach-based school transport are identified. The most significant safety issue identified is the stakeholders' unawareness of the driver and vehicle condition before and during school trips. When schools request coaches for field trips, the safety and operation conditions of vehicles and drivers are not checked by the schools. Requests are made based on trusting coach operators and their compliance with all the safety guidelines, regulations and standards set by the UK government. However, according to the traffic commissioner's reports, it is hard to assume that all the coach operators are complying with the safety guidelines and standards. This reflects that the problem is not with the existing regulation but with the operator compliance with the regulation. This requires an urgent action before more children lives are put at risk.

Chapter 5
Proposed Safety Transport Framework

5.1 Introduction

This chapter discusses the development of a proposed safety transport framework to help schools and parents to choose fully compliant coach operators. It also provides safety recommendations to coach operators to improve their fleet safety. Five-steps are involved in the framework providing the theoretical underpinning of the framework. Further, the framework is expressed mathematically and tested with real data. The chapter concludes by presenting the results of testing of the framework.

5.2 Framework Design Process

The development of the framework was guided by the information obtained from literature search and the analysis of two surveys which gathered views of stakeholders. In addition, the analysis of data on coach accidents obtained from the UK government's databases has influenced the framework. Further, the framework is developed to address the significant issues and requirements identified in chapter 4.

5.3 The Proposed Safety Framework

The purpose of the framework is to reduce the malpractices and also bridge the knowledge gap that exists amongst the stakeholders of coach-based school transport. The framework can also be used to provide information of safety compliance of coach operators, as well as guiding them to improve the safety of their fleet.

The proposed safety framework consists of five steps: data acquisition, data verification, data weight assignment, safety score calculation and intelligent data analysis, as shown in Figure 5.1. In Step 1, data from coach operators relating to the safety aspects of their coaches and drivers are obtained. The data collected is then verified using the government repositories (DVSA 2016b, DVLA 2017b) in Step 2. In step 3, weight points are assigned to the verified data. Safety scores are calculated from the weight points allocated to the operators, their coaches and drivers in Step 4. The scores are then used to sort the coach operators in respect of their safety. To be precise, the framework is designed in a way to find the safest coach and driver pair amongst any number of coach operators. In Step 5, the framework analyses the coach operator's data and provide safety recommendations to improve their felt safety levels.

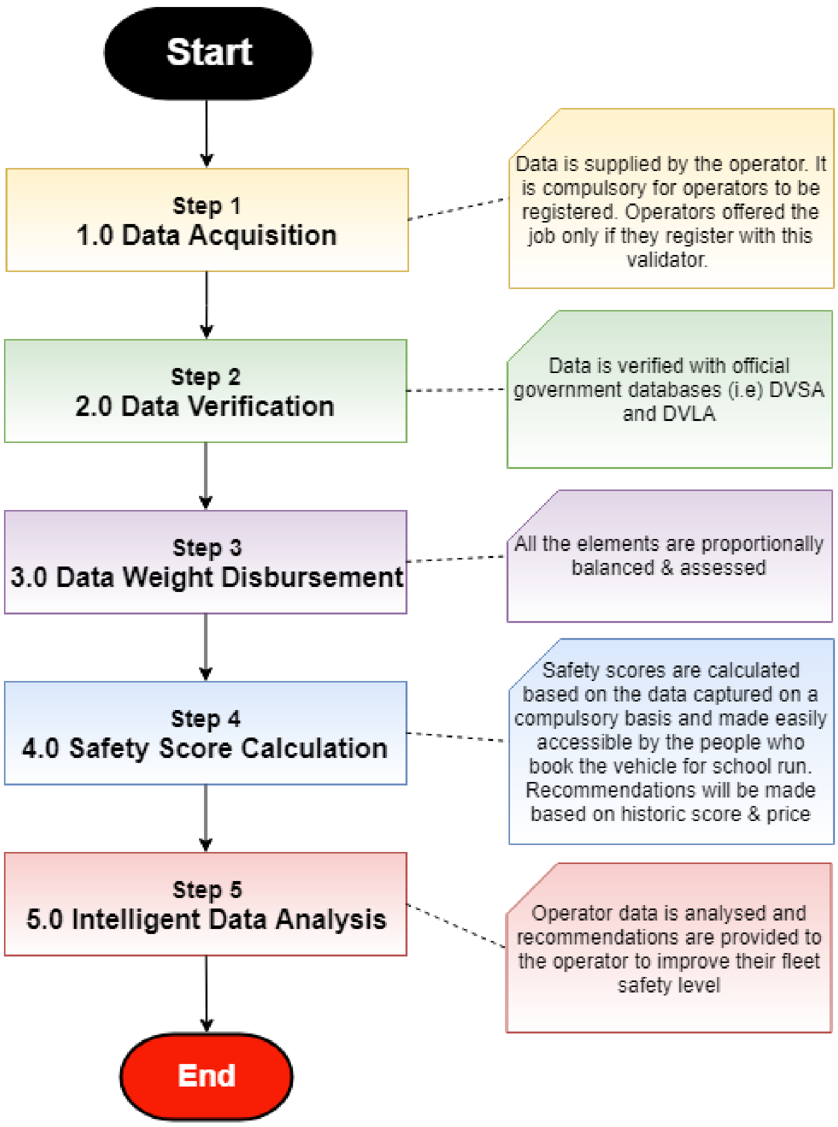


Figure 5.1 - Overview of the proposed safety framework

Figure 5.2 shows more details of the proposed safety framework. Each step has its own set of processes represented as sub-steps which are explained in detail in section 5.3.1 to 5.3.5.

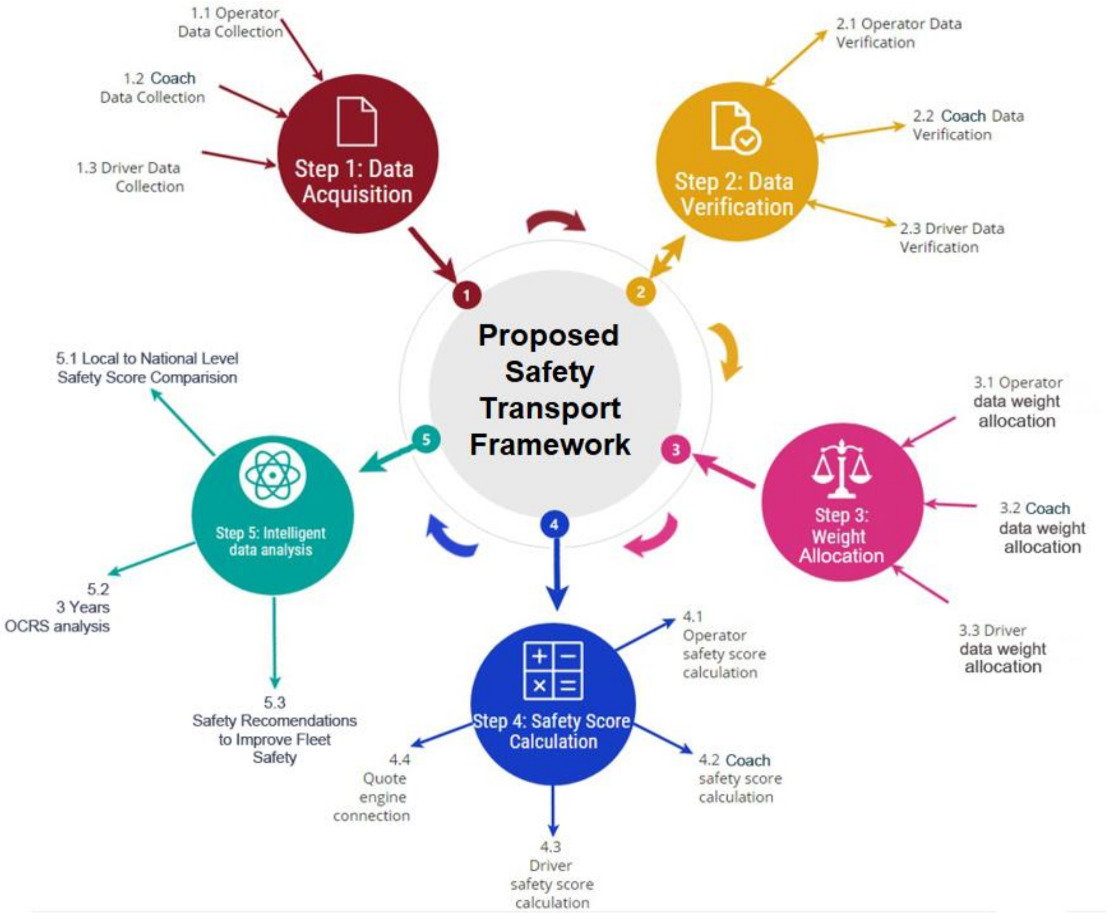


Figure 5.2 - Sub-steps of the proposed safety framework

5.3.1 Step 1: Data Acquisition

The first step in this framework is data acquisition. Figure 5.3 shows the detailed illustration of data collection. In this step, the data of a coach operator (i.e. operator licence number and OCR scores (see section 5.3.1.1)), relevant information about their coaches (i.e. daily "first use" and "last use" checks, (MOT) test certificate, valid insurance and road tax (see section 5.3.1.2)) and drivers (i.e. penalty points on his/her license, (DBS) and driving hours check (see section 5.3.1.3)) are determined and collected in parallel. The data of the coach operator, their coaches and drivers were determined according to the safety standards set by DVSA and DVLA for coach operators in the UK. (DVSA 2011, 2013, 2014a, 2014b, 2014c, 2016c, VOSA 2011, DVLA 2017b). Once all the data is obtained from the operators, it is sent to Step 2 for verification as shown in Figure 5.3.

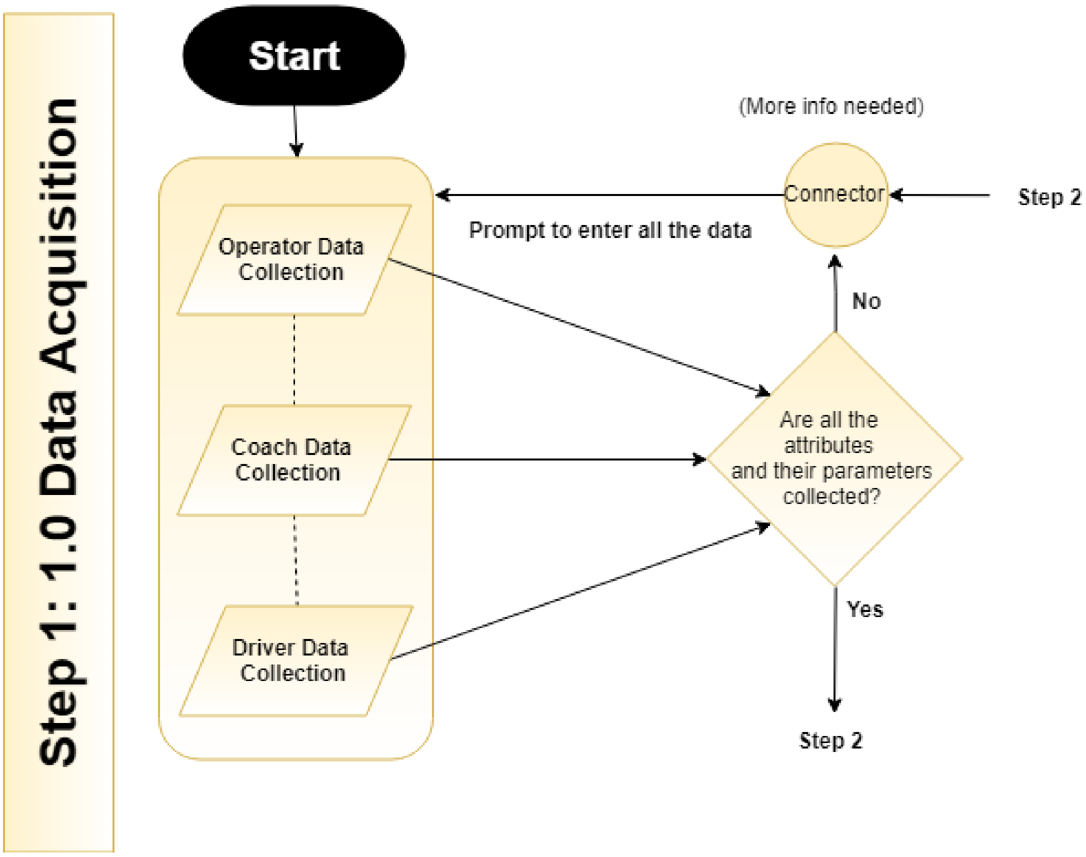


Figure 5.3 - Detailed illustration of data collection (Step 1 of the safety transport framework)

5.3.1.1 Operator Data Collection

In the UK, DVSA awards an Operator Compliance Risk Score (OCRS) to each coach operator indicating the level of safety operated by its fleet. OCRS is used by the DVSA to decide whether a coach should go through safety inspection or not. When OCRS is high, it is more likely for a coach to be inspected. There are three categories in OCRS:

Roadworthiness (ROCRS), Traffic (TOCRS) and Combined (COCRS) (DVSA 2016b). ROCRS is calculated based on the number of defect points identified during roadside inspections of a coach (see equation 5.1). TOCRS is calculated based on the number of offence points received during the roadside inspections (see equation 5.2). COCRS is calculated based on the total number of defect points and offence points (see equation 5.3). OCRS is represented by four bands. They are Green (Low – risk operator), Amber (Medium risk operator), Red (High – risk operator) and Grey (unknown operator) (DVSA 2016d). Depending on the points received for each category during a 3-year rolling period, the OCRS band is determined as shown in Figure 5.4. Table 5.1 provides more detail on how the bands are awarded.

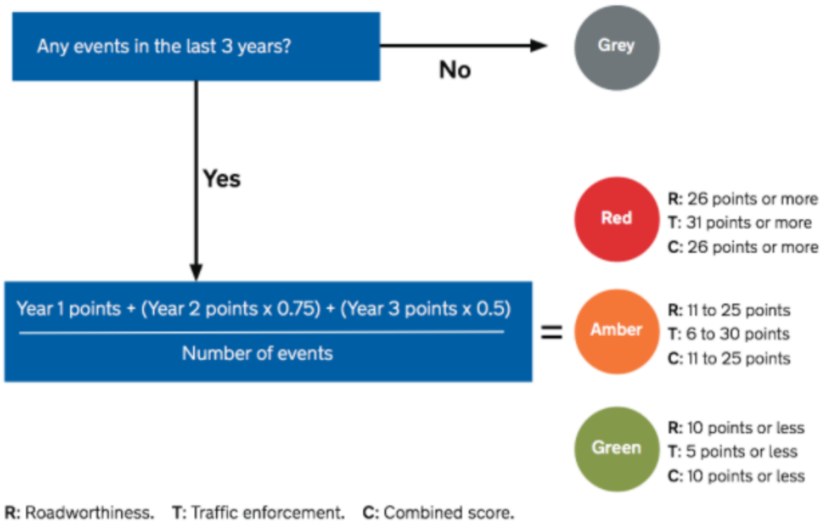


Figure 5.4 - OCRS Calculation (DVSA 2016b)

Table 5.1 - OCRS Band Scoring Guide (DVSA 2016b)

OCRS band	Roadworthiness	Traffic	Combined
Green	10 defect points or below	5 offence points or below	10 defect points or below
Amber	Between 11 and 25 defect points	Between 6 and 30 offence points	Between 11 and 25 defect points
Red	26 defect points or over	31 offence points or over	26 defect points or over
Grey	No score	No score	No score

For example, consider an operator who has been operating for less than a year and receives 200 roadworthiness defect points from 4 inspections and 150 traffic offence points from 2 inspections (Please refer (DVSA 2016b) for the list of all the defect and offence points). To calculate ROCRS, equation 5.1 is used,

$$ROCRS = \frac{\text{Year 1 points (defect)} + (\text{Year 2 points x 0.75}) + (\text{Year 3 points x 0.5})}{\text{Number of inspections}} \quad (5.1)$$

By applying the example values of roadworthiness (200 defect points from 4 inspections) in the equation 5.1,

$$ROCRS = \frac{200 + (0 \text{ x } 0.75) + (0\text{x } 0.5)}{4} = 50$$

This puts the operator in Roadworthiness Red band. Similarly, to calculate TOCRS, equation 5.2 is used.

$$TOCRS = \frac{\text{Year 1 points (offence)} + (\text{Year 2 points x 0.75}) + (\text{Year 3 points x 0.5})}{\text{Number of inspections}} \quad (5.2)$$

Applying the example values of traffic (150 offence points from 2 inspections) in the equation 5.2.

$$TOCRS = \frac{150 + (0 \text{ x } 0.75) + (0\text{x } 0.5)}{2} = 75$$

This puts the operator in the Red band. To calculate the COCRS, equation 5.3 is used.

$$COCRS = \frac{Roadworthiness\ defect\ points + Traffice\ offence\ points}{\text{No. of Roadworthiness inspections} + \text{No. of Traffic inspections}} \quad (5.3)$$

By substituting the example values of roadworthiness and traffic values in equation 5.3.

$$COCRS = \frac{200 + 150}{4 + 2} = 58.33$$

This puts the operator in the red band. COCRS/ROCRS/TOCRS are updated by DVSA every week (DVSA 2016b).

To conclude, during Step 1, detailed information about a coach operator such as ROCRS, TOCORS, COCRS are collected. For the purpose of this thesis, these scores will be referred to as attributes and the OCRS bands will be referred to as parameters. Table 5.2 shows these attributes and their parameters. (Note: Coaches' and drivers' data are also represented as attributes and parameters in Section 5.3.1.2 and 5.3.1.3 respectively)

Table 5.2 - Coach operator attributes and their parameters, for selecting relevant parameters

Operator Attributes	Operator Parameters	Reference
1. License number	Number	(DVSA 2011) (DVSA 2016b)
2. Roadworthiness OCRS (ROCRS)?	Green/Amber/Red/Grey	
3. Traffic OCRS (TOCRS)?	Green/Amber/Red/Grey	
4. Combined OCRS (COCRS)?	Green/Amber/Red/Grey	

5.3.1.2 Coach Data Collection

MOT test is an annual test of vehicle safety, roadworthiness aspects and exhaust emissions test required in the UK. It is required by law that a coach must have a valid MOT test certificate, insurance and road tax to run legally on the road. Therefore, it is vital to check this information along with the other safety checks.

"First use check" is crucial for a coach journey as it helps the driver to identify any faults in the vehicle may have before the start of a journey. "Last use check" is performed once the driver completes a journey. If any defects identified during the check, it has to be rectified before the next journey. Detailed information in respect of "first use check" and "last use check" for each coach is collected and recorded.

Table 5.3 - Coach attributes and their parameters, for selecting relevant parameters

Coach Attributes	Parameters	Reference
1. Coach registration number		(DVSA 2011) (DVSA 2018)
2. Valid MOT test certificate/Road Tax/Insurance?	Yes/No	
3. "first use" and "last use" check carried out properly for each vehicle?	Yes/No	
4. Are the defects identified during the safety checks rectified before the journey?	Yes/No	

5.3.1.3 Driver Data Collection

In the UK, drivers can be fined by courts for motoring offences and penalty points can be endorsed on their driving license. Penalty points on the license can indicate the quality of driving and therefore be used to determine the driver's driving safety level. Penalty points will stay on the driving license between 4 to 11 years, depending on the offence. Drivers can be disqualified from driving if they build up to 12 penalty points or more within three years (6 points or more, if they are new drivers holding their licence for less than 2 years) (DVLA 2017b). In addition, drivers are expected to be driving in legal driving hours (allowed up to 9 hours per day (VOSA 2011)).

Table 5.4 - Driver attributes and their parameters, for selecting relevant parameters

Driver Attributes	Parameters	Reference
1. Driver license number		(DVSA 2011, DVLA 2017b)
2. DBS checked?	Yes/No	
3. In legal driving hours? (allowed up to 9 hours per day)	Yes/No	
4. Number of points on driver license whose experience less than 2 years?	1-6	
5. Number of points on driver license whose experience more than 2 years?	1-12	

Once all the required data is collected from the coach operators, the data is verified using official/source databases as discussed in section 5.3.2.

5.3.2 Step 2: Data Verification

It is important to verify the operators' data to check its authenticity. Figure 5.5 shows the data verification process in detail. Subsequent to obtaining the data from the operator, operator data can be verified using the DVSA database. Their coaches data can be verified using the safety process (See section 5.3.2.2) and their driver data can be verified using the DVLA database and the safety process. Once the data is verified with their authentic sources, it is then compared with the data entered by the coach operator. If they match, then the data is sent to step 3 for data weight assignment. At the same time, the reasons for the OCR scores of an operator (i.e) number of inspections and defect numbers (DVSA 2016b) are retrieved from the DVSA and sent to Step 5 for further processing as shown in Figure 5.5.

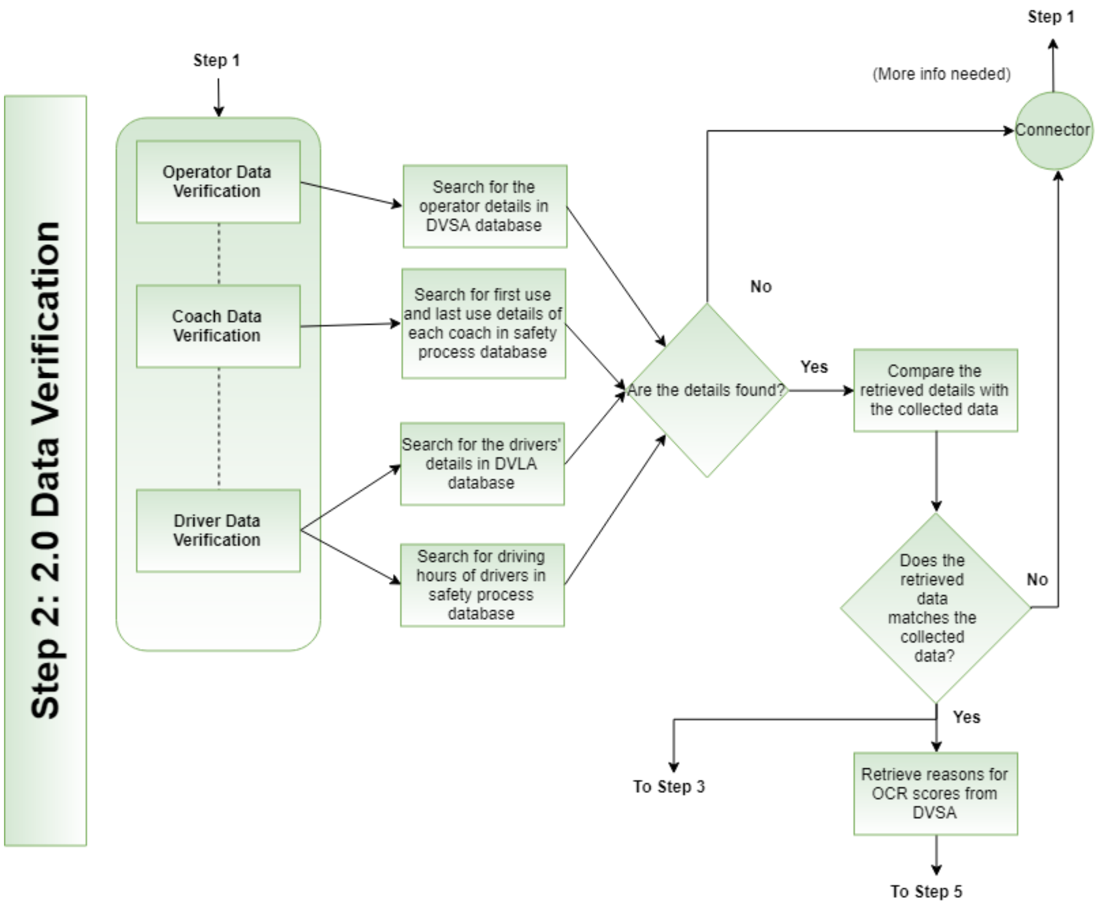


Figure 5.5 - Detailed illustration of data verification process (Step 2 of the safety transport framework)

5.3.2.1 Operator Data Verification

Operator data can be retrieved from the DVSA database using the operator licence number to compare and verify it with the information obtained from the operator. The reason to collect and verify operator data is to avoid the risk of using outdated data due to latency in updating the DVSA database with the OCRS scores. The DVSA database is updated every Saturday of the week and any changes which may occur between Sunday and Friday will not be instantly incorporated into the database (DVSA 2016b). Table 5.5 shows the Operator attributes and their parameters along with the sources of their verification.

Table 5.5 - Coach operator attributes, parameters and verification sources

Operator Attributes	Operator Parameters	Source
1. License number	Number	Coach operator
2. Roadworthiness OCR Score	Green/Amber/Red/Grey	DVSA
3. Traffic OCR Score	Green/Amber/Red/Grey	DVSA
4. Combined OCR Score	Green/Amber/Red/Grey	DVSA

5.3.2.2 Coach Data Verification

Data verification for coaches is slightly different compared to the operators. Table 5.6 shows the coach attributes and parameters along with the verification sources. In Table 5.6, attribute numbers 2 is verified by DVSA, 3 and 4 by the safety check process that is created in this thesis as shown in Figure 5.6. (Note: attributes and parameters are verified for every coach).

Table 5.6 - Coach attributes, parameters and verification sources

Coach Attributes	Coach Parameters	Source
1. Coach registration number(s)		

	Numbers	Coach operator
2. MOT/Road Tax/Insurance	Yes/No	DVSA
3. First use and last use check	Yes/No	Safety process database
4. Rectification of identified defects	Yes/No	Safety process database

Proposed Safety Check Process: The proposed "safety check" process consists of two options: driver interface and mechanic interface as shown in Figure 5.6. Driver interface option facilitates login, enabling driver access to: coach check and driving hours check. With Coach Check, the driver can perform "first use" or "last use check" for a coach using a mobile application. The details will be stored in the safety process database. If any defect is detected during the checks, a message consisting of the details will be sent to the mechanic of the corresponding operator which can be accessed by the mechanic via the mechanic interface option. Once the mechanic rectifies a defect, it will add the record to the safety process database. Further, drivers can record their driving hours from tachographs (a device that stores driver's driving hours). Safety check and driving hours details can be accessed during the data verification process to verify the "first use" or "last use check" through a dedicated interface from the safety process database as shown in Figure 5.6.

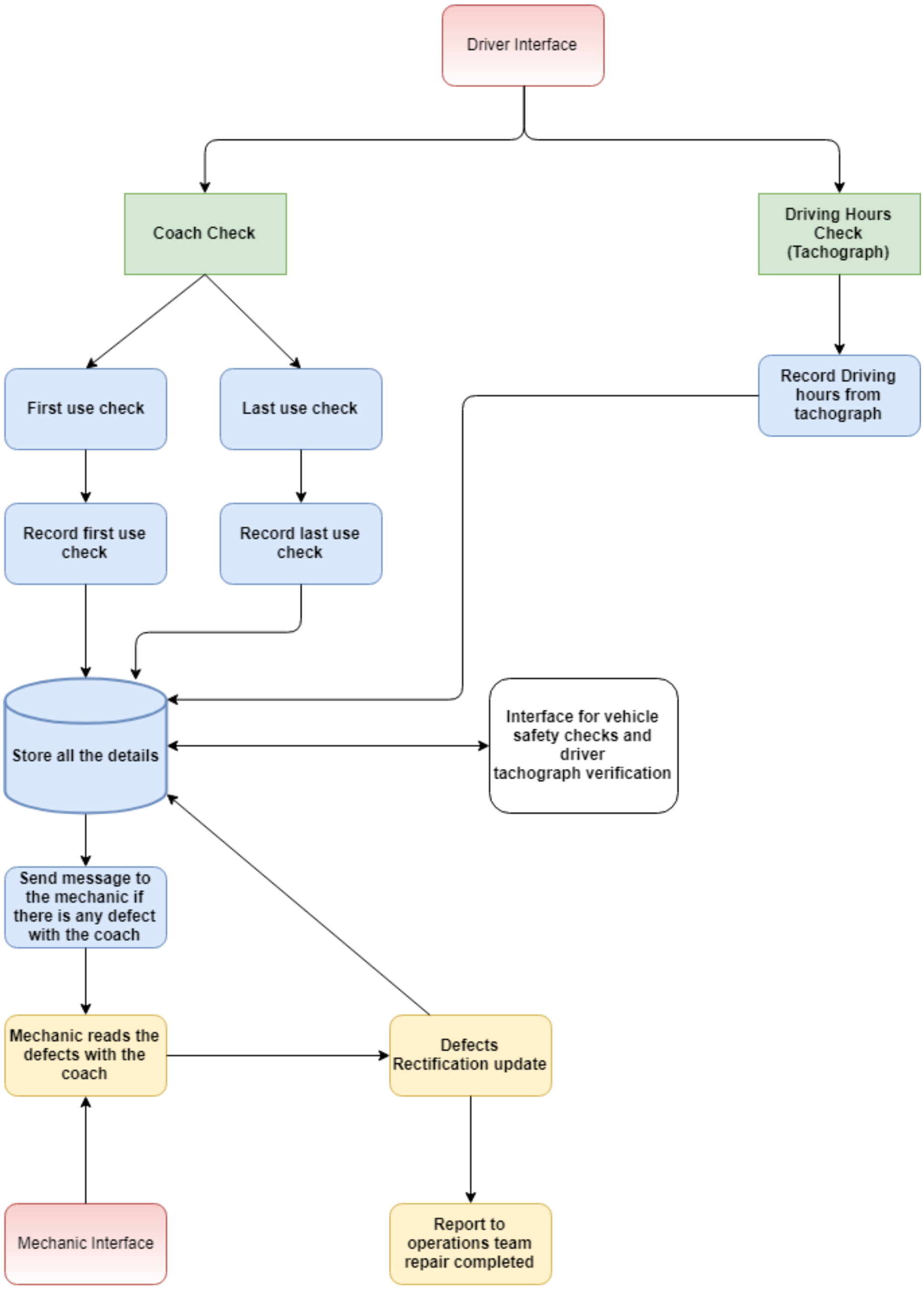


Figure 5.6 - Safety check process for recording "first use" and "last use" checks and driver tachograph data

5.3.2.3 Driver Data Verification

Driver licence numbers (attribute) are used to retrieve the DVLA penalty points on the licence. These points are then compared with the number of points entered by the coach operators during the data acquisition step. If they match, then the number of points on the license is verified. Table 5.7 shows the driver attributes and their parameters verification sources. Attribute number 2 is verified by DBS, whereas attribute number 3 is verified by the contents of the information in the safety process database through a dedicated interface as shown in Figure 5.6.

Table 5.7 - Driver attributes, parameters and verification sources

Driver Attributes	Driver Parameters	Source
1. Driver license numbers (s)	Numbers	Coach operator
2. DBS checked?	Yes/No	DBS
In legal driving hours? (allowed up to 9 hours per day)	Yes/No	Safety process database
3. Number of points on driver license whose experience less than 2 years?	1-6	DVLA
4. Number of points on driver license whose experience more than 2 years?	1-12	DVLA

5.3.3 Step 3: Weight Allocation

Before computing the safety scores for operators, weight points are allocated to coach operator data, based on the level of importance of the attributes and parameters of the data (VOSA 2011, DVSA 2014b, DVLA 2017b). Figure 5.7 shows the illustration of the weight point allocation. Sections 5.3.3.1 to 5.3.3.3 provide a detailed explanation on the weight allocation criteria and Section 5.3.4 explains the safety score calculation in detail.

5.3.3.1 Operator Data Weight Allocation

Using the OCRS band scoring guide (see Table 5.1), an equivalent weighting criteria of 100 to 1 is created for each operator attributes as shown in Table 5.8. (The weighting criteria of 100 to 1 is used to bring standardisation in weighting so that the comparison across different attributes can be possible (Woodcock et al. 2004)). The roadworthiness defect points from which ROCRS is then calculated, ranging from 1 to 400 (DVSA 2016b). Based on the range of Green and Amber defect points, which is 1 to 25 (see Table 5.1), equivalent weigh points of 100 to 76 is allocated. For the Red parameter, the defect points vary from 26 to 400. Equivalent weight points are allocated evenly to 26 to 400 defect points range with 0.200 weight points each. For the Grey parameter, 100 weight points are allocated as the operator is yet to be given a score by DVSA as shown in Table 5.8.

Table 5.8 - Operator parameters' weight allocation

Weight allocation				
1. Roadworthiness OCRS (ROCRS)				
Parameters	Green	Amber	Red	Grey
Defect points	1 to 10	11 to 25	26 to 400	0
Weight points	100 to 91	90 to 76	75 to 1	100
2. Traffic OCRS (TOCRS)				
Parameters	Green	Amber	Red	Grey
Offence Points	1 to 5	6 to 30	31 to 300	0
Weight points	100 to 96	95 to 71	70 to 1	100

3. Combined (Roadworthiness + traffic) OCR Score				
Parameters	Green	Amber	Red	Grey
	1 to 10	11 to 25	26 to 350	0
Weight points	100 to 91	90 to 76	75 to 1	100

The traffic offence points from which the TOCRS is calculated ranges from 1 to 300 (DVSA 2016b). Based on the Green and Amber offence points range, which is, 1 to 30 (see Table 5.1), equivalent weight points of 100 to 71 are allocated. For the Red band, the offence points vary from 31 to 300. Equivalent weight points are allocated evenly to 31 to 300 penalty points range with 0.259 weight points each. COCRS defect points range from 1 to 350 (DVSA 2016b). Based on the Green and Amber defect point range, which is 1 to 25 (see Table 5.1), equivalent weight points of 100 to 76 are allocated. For the Red band, the defect points vary from 26 to 250. Equivalent weight points are allocated evenly to 26 to 250 defect points range with 0.230 weight points each.

5.3.3.2 Coach Data Weight Allocation

After the coach data verification process, weighting criteria for coach attributes are created as shown in Table 5.9. All the coach attributes listed in Table 5.9 are mandatory for a coach to legally operate in the UK (DVSA 2016c). Therefore, they are given with an equal level of importance (i.e. all the parameters are allocated with equal weighting factors (DVSA 2014b). If there is no defect detected during the "first use" and "last use check", then Not Applicable parameter (N/A) can be used.

Table 5.9 - Weight allocation to coach parameters'

Weights allocation			
1. MOT/ Road Tax/ Insurance			
Attribute	MOT	Tax	Insurance
Parameter and its weight points	Yes- 1 No- 0	Yes- 1 No- 0	Yes- 1 No- 0
2. First use check			
Attribute	First use check done	Defects rectified	
Parameter and its weight points	Yes- 1 No- 0	Yes- 1 No- 0 N/A- 1	
3. Last use check			
Attribute	Last use check done	Defects rectified	
Parameter and its weight points	Yes- 1 No- 0	Yes- 1 No- 0 N/A- 1	

5.3.3.3 Driver Data Weight Allocation

After the driver data verification process, weight points are allocated to the driver's parameters as shown in Table 5.10. Attribute number 1 and 2 shown in Table 5.10 are mandatory for driving a coach legally in the UK. The weighting point 6.5 is assigned to regulate the total driver weight point value. It does not represent any special value. For example, drivers either get 6.5 weight points if they have DBS check or 0 if they do not. For the driver licence points parameters, the UK government's penalty point system is used to allocate equivalent weight points (DVLA 2017b). Points on the license indicate the quality of driving and can be used to determine the driving safety level. New drivers with less than 2 years of holding the license are allowed up to 6 penalty points on their license (DVLA 2017b). Therefore, the penalty points range from 0 to 6 and the equivalent weight point is allocated from 12 to 0. Drivers who held their licence more than 2 years can get up to 12 points on their licence (DVLA 2017b). Therefore, the penalty points range from 0 to 12. The equivalent weight point allocated from 12 to 0 as shown in Table 5.10.

Table 5.10 - Driver parameters' weight point assignment

Weights allocation	
Attribute	Parameters and its weight points
1. DBS checked?	Yes- 6.5 No-0
2. In legal driving hours? (allowed up to 9 hours per day)	Yes-6.5 No-0
3. Points on driver license	

1 to 2 years' Experience	0-6 points
Weight points	12 to 0
2+ years	0 to 12 points
Weight points	12 to 0

5.3.4 Step 4: Safety Score Calculation

Once the weighting points are assigned, individual safety scores for an operator, their coaches and their drivers can be calculated as shown in Figure 5.7. A maximum score of 100 is used to represent these safety scores to create a standard scale so that comparisons between them can be made (Woodcock et al. 2004). These safety scores are then used to identify the safest vehicle and driver combination for each operator to be used for a school journey. The output from Step 4 can be divided into (a). "Stand-alone framework" and (b). "Extended framework".

Stand-alone framework:

The purpose of the stand-alone framework is to help the customers (school Headmasters/parents) to be aware of the safety level of coach operators. Currently, they seek the help of local council or use the Internet to find a coach operator for a school journey (Department for Education 2014). The safety scores produced at the end of Step 4 can help them to select the safest coach operator. The framework is called stand-alone since it does not depend on any external sources such as quote engines. Sections 5.3.4.1 to 5.3.4.3 explains the calculation of the safety score in detail.

Extended framework:

The Stand-alone framework only provides information on the safety level of a coach operator. However, to get a price quotation for a journey, it must be connected to a quotation engine which is usually owned by a coach broker. A quote engine often connects to several coach operators for retrieving prices for a journey. If the safety scores are provided to a quote engine, a price quotation for a school journey along with safety scores can be produced. Section 5.3.4.4 explains this in detail.

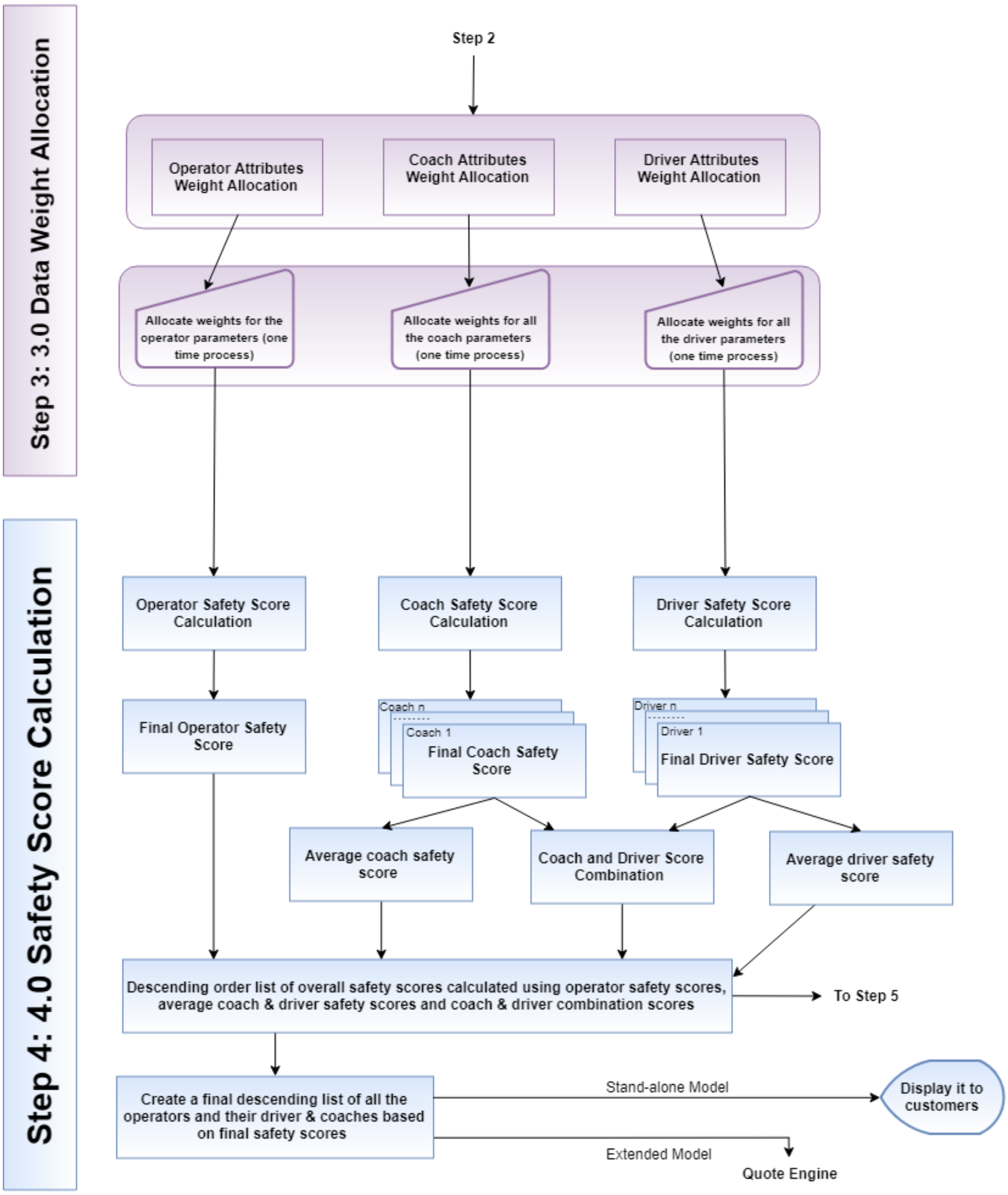


Figure 5.7 - Detailed view of weight allocation and safety score calculation (Step 3 and Step 4 of the safety transport framework)

5.3.4.1 Operator Safety Score Calculation

The operator safety score is calculated using equation 5.4 and the weight points obtained by the operator's attributes listed in Table 5.8.

$$Operator\ Safety\ Score\ (os) = \frac{weight\ points}{\text{Total weight points}} * 100 \tag{5.4}$$

Based on Table 5.8, the maximum weight points possible is 300. The maximum value that equation 5.4 produces is 100.

5.3.4.2 Coach Safety Score Calculation

The coach safety score is calculated using equation 5.5 and the weight points obtained from the coach attributes listed in Table 5.9. Based on Table 5.9, the maximum weight points possible is 7.

$$Coach\ Safety\ Score\ (cs) = \frac{weight\ points}{\text{Total weight points} - \text{N/A}\ weight\ points} * 100 \tag{5.5}$$

In equation 5.5, "N/A weight points" indicates the total number of weight points obtained by the N/A parameters. N/A parameter is used in equation 5.5 to eliminate an attribute which is not applicable to a particular coach. By doing this, the effect of a not applicable attribute on the safety score can be avoided. Coaches must obtain the maximum score of 100 to qualify for a journey.

5.3.4.3 Driver Safety Score Calculation

The driver safety score is calculated using equation 5.6 and the weight points obtained from the driver's attributes listed in Table 5.10. Based on Table 5.10, the maximum weight points possible is 25.

$$Driver\ Safety\ Score\ (ds) = \frac{Weight\ points}{\text{Total weight points}} * 100 \tag{5.6}$$

In equation 5.6, "weight points" and "total weigh points" are similar to equation 5.4 but represents driver attributes. Drivers need to obtain a passing score of 52 or higher to qualify for a journey. The reason being, DBS and applying the maximum driving hours (see Table 5.10) are compulsory, their total weights along with the minimum weight from the license points are considered as the passing score of 52. (i.e) 6.5+6.5 = 13. 13/25*100=52. (Passing score of 52 is set to standardise the passing score for all the drivers so that the comparisons between them can be made (Woodcock et al. 2004). The remaining driver safety score (48) varies depending on the driver licence points.

Once the operator, coaches and drivers safety scores are calculated, the average safety scores of coaches (*ac*) and drivers (*ad*) are calculated along with the total number of driver and vehicle combinations (*cdc*). These scores are then used to find the safest driver and coach pair from a safe operator for a school journey. The detailed mathematical modelling for safety score calculations are presented in section 5.4.

5.3.4.4 Quote Engine Connection

The quote engine is widely used by many coach brokers in the UK (Jamie 2018). A quote engine calculates a quotation for a journey. It uses data from all the operators who have registered for it, provides a quotation for a journey by each operator, and makes them available to the customers. Connecting the validator to the quote engine will enable customers to receive information about the safety operation level of a coach operator, their coaches and drivers as well. This will enable the customers to make an informed decision. On the coach operator side, the coach and the driver who are available at the time of a journey are only included in the quotation.

5.3.5 *Step 5: Intelligent data analysis*

The OCR scores from step 2 and the safety scores from step 4 are used for a further intelligent analysis as shown in Figure 5.8. The safety scores from step 2 are used to rank operators, their coaches and drivers among all the operators in the UK at local, regional and national levels. Further, a 3-year OCRS analysis and recommendations to improve coach operator's fleet safety is also provided.

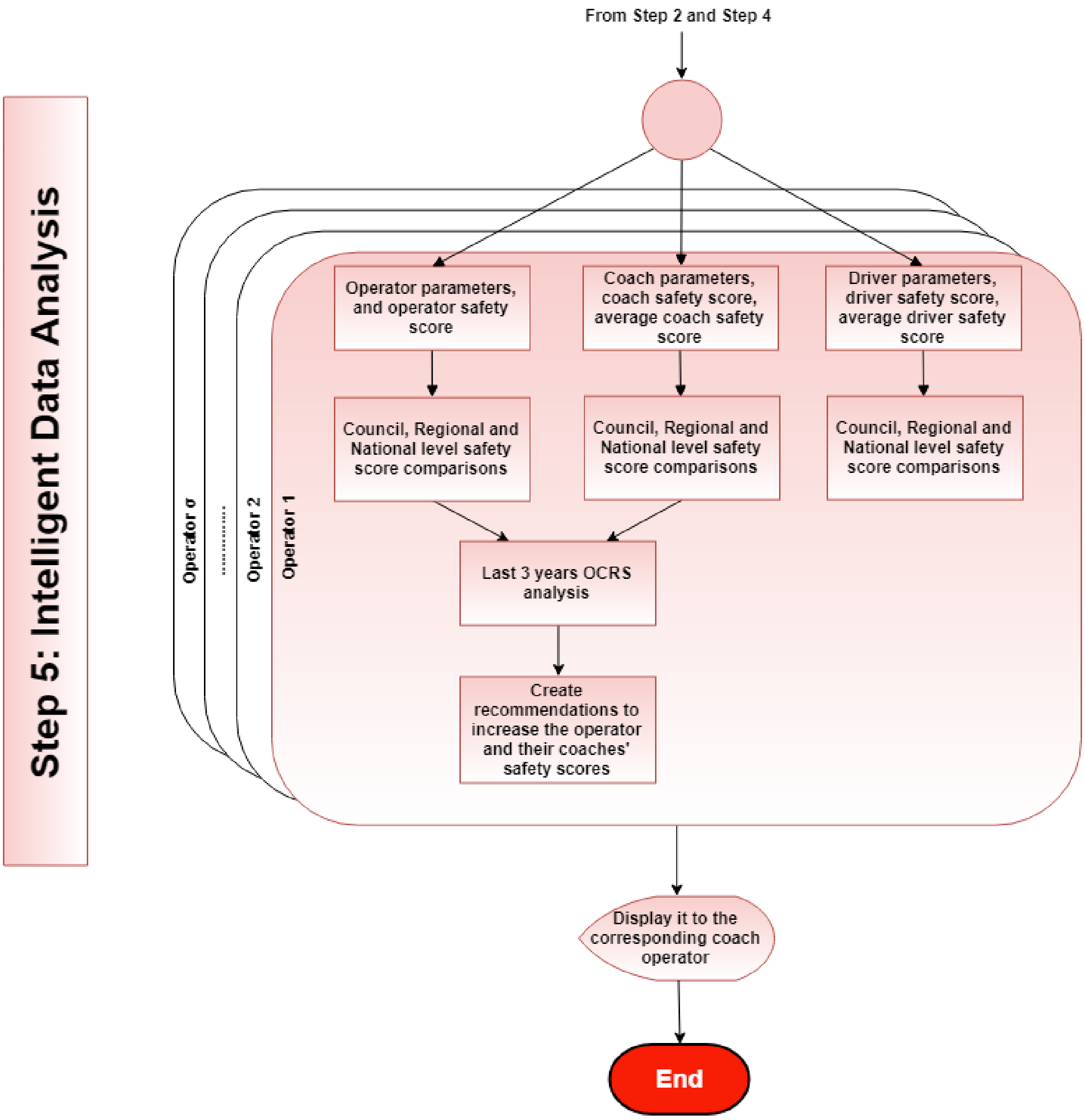


Figure 5.8 - Detailed view of the process for Intelligent Data Analysis (Step 5)

Figure 5.9 shows a different view of step 5. The OCR scores are retrieved from DVSA and processed through Step 2 to Step 4 using the safety transport framework. The output of Step 5 can be divided into 3 parts: Part (a) provides safety ranks for an operator, based on their local, regional and national level safety scores (See section 5.3.5.1.). Part (b) provides an analysis of an operator's 3-year OCR score patterns (See section 5.3.5.2.). Part (c) provides results and recommendations to improve the coach operator's fleet safety (See section 5.3.5.3.).

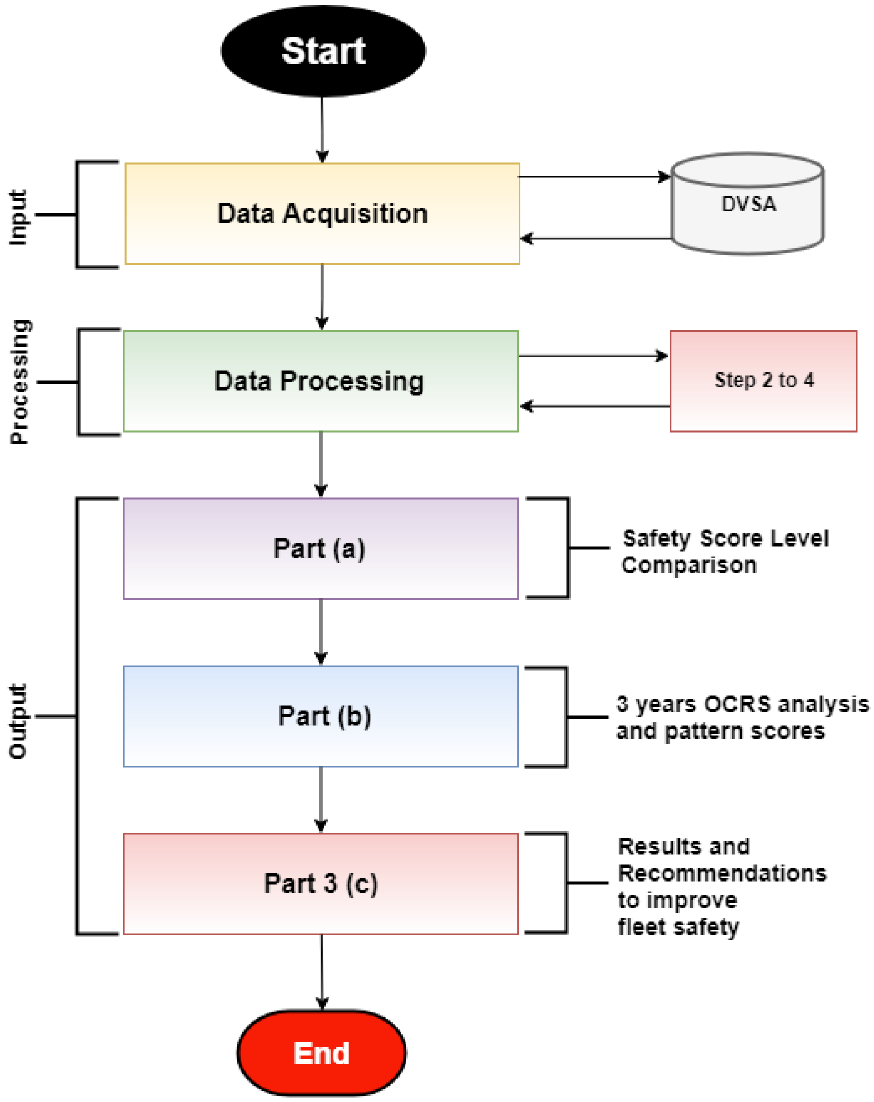


Figure 5.9 - An alternative illustration of Intelligent Data Analysis (Step 5)

5.3.5.1 Part (a) Safety Score Level Comparison

Safety scores for coach operators, their coaches and drivers are calculated at the end of Step 4 of the safety transport framework (Section 5.3.4). Based on their safety scores, coach operators are ranked at local, regional and national levels respectively. This will inform the operator of their operation safety levels, compared to their competitors. Following is the flowchart which represents the safety score comparison.

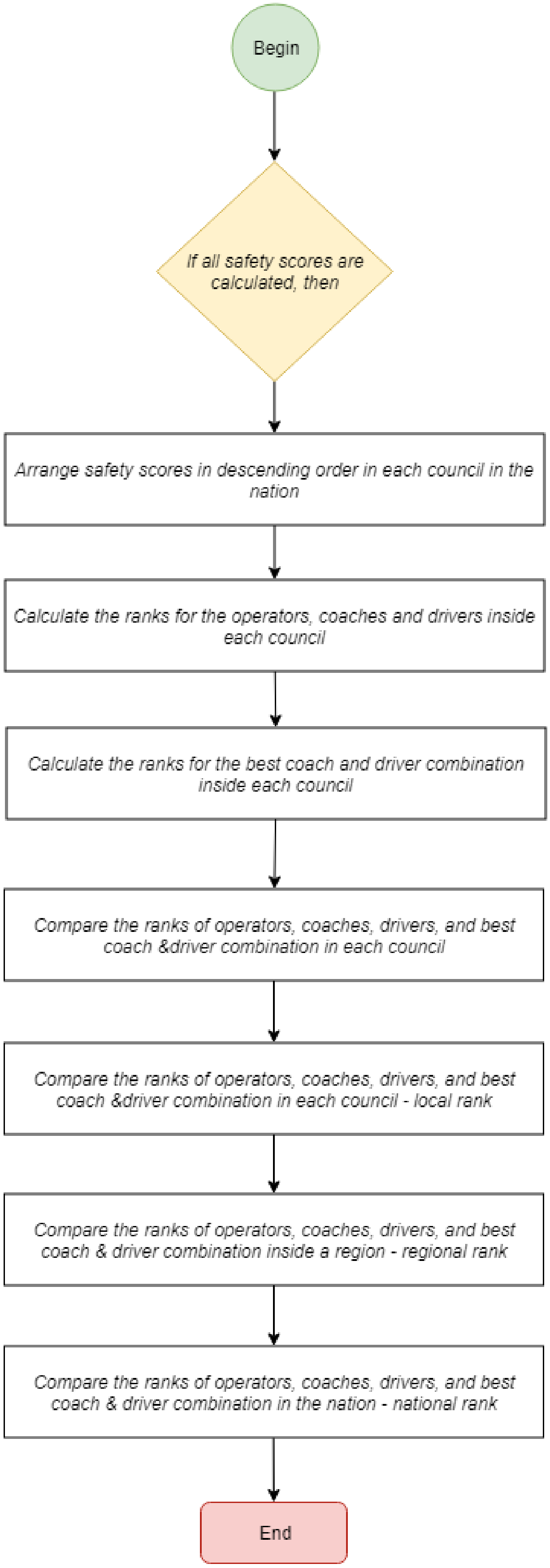


Figure 5.10 - Flow chart of safety score comparison (Part a)

5.3.5.2 Part (b) 3 years OCRS Analysis and Pattern Scores

Analysing the combined OCR (COCR) scores over the years can reveal the fleet's performance and maintenance during that period. This will be helpful to see whether an operator is improving its operation safety of its fleet or doing the exact opposite. To analyse the COCRS combinations for an operator over three years, it is necessary to consider all the possible combinations and sort them in most safe order. Table 5.11 shows possible overall COCRS for a 3 years period. To sort them in safety order, pattern scores are used. To calculate the pattern scores, equation 5.6 is used which is based on the UK government weighting system (DVSA 2016b).

$$\text{Pattern Score} = (\text{Year } 3 * 0.5) + (\text{Year } 2 * 0.75) + (\text{Year } 1 * 1) \qquad (5.7)$$

Pattern scores are calculated based on the weighted average for year 3, 2 and 1 respectively. Depending on the COCRS bands the weights will be: Green = 3, Amber = 2 and Red = 1. For example, take the first row of Table 5.11 and apply the values in equation 5.7. Pattern Score = (3*0.5) + (3*0.75) + (3*1) = 6.75. equation 5.7 is repeated for all the combinations and pattern scores are calculated. Pattern scores range from 6.75 to 1.875 marking best maintenance to worst maintenance. Some of the combinations will have the same safety score as shown in Table 5.11. To break the tie, recent year OCR score is given priority. For an example, No. 4 and No. 5 have the same safety score but No. 4 is given with higher priority because the present year (Year 3) OCRS is Green compared to the No. 5 Amber. To show the trends and ties, values are colour coded as shown in Table 5.11. Please refer Table 5.12 for the analysis provided based on the last three years OCRS.

Table 5.11 - Possible three years COCRS combinations with pattern scores

No.	Year 3	Year 2	Year 1	Pattern Score
1	green	green	green	6.75
2	amber	green	green	6.25
3	green	amber	green	6
4	red	green	green	5.75
5	green	green	amber	5.75
6	amber	amber	green	5.5
7	green	red	green	5.25
8	amber	green	amber	5.25
9	red	amber	green	5
10	green	amber	amber	5
11	amber	red	green	4.75
12	red	green	amber	4.75
13	green	green	red	4.75
14	amber	amber	amber	4.5
15	red	red	green	4.25
16	green	red	amber	4.25
17	amber	green	red	4.25
18	red	amber	amber	4
19	green	amber	red	4
20	amber	red	amber	3.75
21	red	green	red	3.75
22	amber	amber	red	3.5
23	red	red	amber	3.25

24	green	red	red	3.25
25	red	amber	red	3
26	amber	red	red	2.75
27	red	red	red	1.875

Table 5.12 - Three years COCRS analysis

Year 1	Year 2	Year 3	Pattern Score	Analysis
green	green	green	6.75	Your fleet Maintenance is fabulous over the last 3 years.
amber	green	green	6.25	Your fleet Maintenance is fabulous over the last 2 years
green	amber	green	6	Your fleet Maintenance is good
red	green	green	5.75	Your fleet Maintenance is good over the last 2 years
green	green	amber	5.75	Your fleet Maintenance is fair
amber	amber	green	5.5	Your fleet maintenance is good
green	red	green	5.25	Your fleet Maintenance is good
amber	green	amber	5.25	Your fleet Maintenance is fair
red	amber	green	5	your fleet Maintenance is good and improved over the last 3 years
green	amber	amber	5	Your fleet Maintenance is fair
amber	red	green	4.75	Your fleet Maintenance is good
red	green	amber	4.75	Your fleet Maintenance is fair
green	green	red	4.75	Your fleet Maintenance is bad this year
amber	amber	amber	4.5	Your fleet Maintenance is average over the last 3 years
red	red	green	4.25	Your fleet Maintenance is good this year compared to previous years

green	red	amber	4.25	Your fleet Maintenance is fair and improving
amber	green	red	4.25	Your fleet Maintenance is bad this year
red	amber	amber	4	Your fleet Maintenance is fair over the last 2 years
green	amber	red	4	Your fleet Maintenance is bad and degraded over the last 3 years
amber	red	amber	3.75	Your fleet Maintenance is fair
red	green	red	3.75	Your fleet Maintenance is bad
amber	amber	red	3.5	Your fleet Maintenance is bad
red	red	amber	3.25	Your fleet Maintenance is poor but improved this year
green	red	red	3.25	Your fleet Maintenance is very bad
red	amber	red	3	Your fleet Maintenance is bad
amber	red	red	2.75	Your fleet Maintenance is very bad
red	red	red	1.875	Your fleet Maintenance is very worst

5.3.5.3 Part (c)Results and Recommendations to Improve Fleet Safety

To provide safety recommendations, operator roadworthiness OCRS (ROCRS) and traffic OCRS (TOCRS) are used. Safety recommendations are provided based on the offences an operator is committed. The offences data is collected as part of the data acquisition process (See sections 5.3.1 and 5.3.2). Using Table 5.13 possible combined OCRS (COCRS) and defects that might have occurred are listed along with all possible recommendations as shown in Table 5.14. Based on the analysis, the recommendation will be provided for improving operational safety.

Table 5.13 - Possible combinations of roadworthiness and traffic and their outcomes

<table>
<tr><th colspan="2" rowspan="2"></th><th colspan="3">Roadworthiness</th></tr>
<tr><th>Green</th><th>Amber</th><th>Red</th></tr>
<tr><td rowspan="3">Traffic</td><td>Green</td><td>Coaches: Good
Drivers: Good
(Low-risk operator)</td><td>Coaches: Average
Drivers: Good</td><td>Coaches: Bad
Drivers: Good</td></tr>
<tr><td>Amber</td><td>Coaches: Good
Drivers: Average</td><td>Coaches: Average
Drivers: Average
(Medium risk operator)</td><td>Coaches: Bad
Drivers: Average</td></tr>
<tr><td>Red</td><td>Coaches: Good
Drivers: Bad</td><td>Coaches: Average
Drivers: Bad</td><td>Coaches: Bad
Drivers: Bad
(High-risk operator)</td></tr>
</table>

Table 5.14 **-** Recommendations for possible OCRS combinations

Roadworthiness and Traffic OCRS combination	Possible combined OCRS	Roadworthiness and Traffic OCR Scores	Reason for the score	Recommendations
Roadworthiness-Green Traffic - Green	Green	Coaches: Good Drivers: Good Less risk operator	-	Keep up the good work
Roadworthiness-Amber Traffic - Green	Amber	Coaches: Average Drivers: Good	Defect No. 4 or 10	If it is No. 4 – Please ensure that daily walk around checks are carried out properly and the defects identified were rectified.

				If it is No. 10 – Please double check your vehicle for any defects before you go for vehicle annual test.
Roadworthiness- Red Traffic - Green	Red	Coaches: Bad Drivers: Good	Defect No. 1 or 2 or 3 or 5 or 6 or 7 or 8 or 9	If it is No. 1, 3, 5, 7 and 10 – Please maintain your vehicle's tyres, brakes and steering properly and make sure daily safety checks, weekly and annual checks are carried out properly. If it is No. 2, 4, 6 and 8– Please make a sure daily walk around check and weekly maintenance checks are carried out properly.
Roadworthiness- Green Traffic - Amber	Green	Coaches: Good Drivers: Average	-	
Roadworthiness- Amber Traffic - Amber	Amber	Coaches: Average Drivers: Average	Defect No. 4 or 10	If it is No. 4 – Please ensure that daily walk around checks are carried out properly and the defects identified were rectified. If it is No. 10 – Please double check

				your vehicle for any defects before you go for vehicle annual test.
Roadworthiness-Red Traffic - Amber	Red	Coaches: Bad Drivers: Average	Defect No. 1 or 2 or 3 or 5 or 6 or 7 or 8 or 9	If it is No. 1, 3, 5, 7 and 9 – Please maintain your vehicle's tyres, brakes and steering properly and make sure daily safety checks, weekly and annual checks are carried out properly. If it is No. 2, 4, 6 and 8– Please make sure daily walk around check and weekly maintenance checks are carried out properly.
Roadworthiness-Green Traffic - Red	Green	Coaches: Good Drivers: Bad	-	
Roadworthiness-Amber Traffic - Red	Amber	Coaches: Average Drivers: Bad	Defect No. 4 or 10	If it is No. 4 – Please ensure that daily walk around checks are carried out properly and the defects identified were rectified. If it is No. 10 – Please double check your vehicle for any defects before you go for vehicle annual test.

Roadworthiness-Red Traffic - Red	Red	Coaches: Bad Drivers: Bad High-risk operator	Defect No. 1 or 2 or 3 or 5 or 6 or 7 or 8 or 9	If it is No. 1, 3, 5, 7 and 9 – Please maintain your vehicle's tyres, brakes and steering properly and make sure daily safety checks, weekly and annual checks are carried out properly. If it is No. 2, 4, 6 and 8– Please make a sure daily walk around check and weekly maintenance checks are carried out properly.

5.4 Mathematical Model

This section focuses on mathematical modelling for safety transport. Data acquired from each coach operator comprises of attributes (a_n) and parameters (p_m) where n denotes the total number of attributes and m the total number of parameters respectively. An attribute (a_1) may have more than one parameters ranging from p_1, p_2, …, p_b and p_m where p_b denotes "the not applicable parameter" which is necessary to exclude the attributes which are not applicable. Once the data is verified, weight points (w) are then assigned to parameters of their coaches and drivers. The weight points are assigned based on the UK government's scoring system (DVSA 2016d) using the format shown in Table 5.15. In this respect, x_n denotes the total weight points for non-applicable attributes, where x_n=p_b. y_n denotes the total weight points possible when all the attributes have maximum weights, y_n=p_1 + $p_{2\dots}$+p_m and z_n denotes the total weight points obtained by all the attributes, z_n=p_1 + $p_{2\dots}$+p_m. Table 5.15 can be used to assist in assigning parameter weight points to coach operators, their coaches and drivers attributes.

Table 5.15 - Parameters weight allocation format

Attribute Number (a_n)	Parameter 1 weight points (p_1)	Parameter 2 weight points (p_2)	….	Parameter m weight points (p_m)	Parameter p_b weight points (p_b)	Total p_b weight points (x_n)	Total weight points possible (y_n)	Total weight points obtained (z_n)
a_1	w_1	w_2	…	w_m	w_b	x_1	y_1	z_1
a_2	w_1	w_2	…	w_m	w_b	x_2	y_2	z_2
a_3	w_1	w_2	…	w_m	w_b	x_3	y_3	z_3
…	…	…	…	…	…	…	…	…
a_n	w_1	w_2	…	w_m	w_b	x_n	y_n	z_n

Safety scores are then calculated based on the weight points. The mathematical calculations in this model relate to one operator, its fleet and drivers. The same can be applied to any operator. Using equation 5.4, equation 5.8 is formed which shows the calculation of the safety score *(os)* for an operator, where *n* denotes the total number of operator's attributes, z_i the total weight points obtained by all the attributes, y_i denotes the total weight possible when all the attributes have maximum weight points.

$$Operator\ Safety\ Score\ (os) = \left(\frac{\sum_{i=1}^{n} z_i}{\sum_{i=1}^{n} y_i}\right) \times 100 \qquad (5.8)$$

Using equation 5.5, equation 5.9 is formed which shows the calculation of coach's safety score (cs_u), where u denotes the total number of coaches, n denotes the total number of coach attributes. x_i denotes the total weight for non-applicable attributes. Other parameters are similar to equation 5.8,

$$Coach\ Safety\ Score\ (cs_u) = \left(\frac{\sum_{i=1}^{n} z_i}{\sum_{i=1}^{n} y_i - \sum_{i=1}^{n} x_i}\right) \times 100 \qquad (5.9)$$

Using equation 5.6, equation 5.10 is formed which shows the calculation of driver's safety score (ds_e), where e denotes the total number of drivers, n denotes the total number of driver attributes. Other parameters are similar to equations (5.8 and 5.9),

$$Driver\ Safety\ Score\ (ds_e) = \left(\frac{\sum_{i=1}^{n} z_i}{\sum_{i=1}^{n} y_i}\right) \times 100 \qquad (5.10)$$

All the safety scores (os, cs_u and ds_e) are expressed as percentage. One operator may have more than one coach and a driver. In equation 5.11, ac is the average safety scores for all the coaches and u denotes the total number of coaches belongs to an operator and cs_i the safety score for vehicle i respectively.

$$Average\ Safety\ Score\ of\ Coches\ (ac) = \left(\frac{1}{u}\right) \times \sum_{i=1}^{u} vs_i \qquad (5.11)$$

In equation 5.12, ad is the average safety score for the drivers of an operator, e denotes the total number of drivers belongs to the operator, and ds_i denotes the safety score for driver i.

$$Average\ Safety\ Score\ of\ Drivers\ (ad) = \left(\frac{1}{e}\right) \times \sum_{i=1}^{e} ds_i \qquad (5.12)$$

Average safety scores for coaches and drivers are useful information for the recommendation of operators to a customer, as well denoting the safety level of their entire fleet.

To calculate the safety score for a journey, safety score combinations of available coaches and drivers in a fleet are used. To find the best possible driver & vehicle combinations the steps below are followed.

Step 1: The number of possible coach and driver combinations (*cdc*) is calculated using equation 5.13. In this equation, *u* and *e* denote the number of coaches and drivers respectively.

$$Coach\ and\ Driver\ Combination\ (cdc) = u * e \qquad (5.13)$$

Step 2: To find the sample space (Ω) between the vehicle's safety scores and driver's safety scores, equation 5.14 is used. In this equation, *cs* and *ds* denote vehicle and driver safety scores respectively.

$$Sample\ Space\ (\Omega) = \{(cs_1, ds_1), (cs_2, ds_2), \ldots (cs_u, ds_e)\} \qquad (5.14)$$

Step 3: To find the sum for all the combinations, equations 5.15 is used.

$$Sum\ of\ all\ the\ combinations\ (q) = Individual\ Sum\ \{\Omega\} \qquad (5.15)$$

$$q = \{cd_1, cd_2, \ldots \ldots \ldots, cd_{cdc}\}$$

Where, $cd_1=cs_1+ds_1$, $cd_2=cs_2+ds_2, \ldots cd_c=cs_u+ds_e$. (cs_u+ds_e denotes the last possible coach and driver combination) To find the average for individual combinations of q, equation 5.16 is used.

$$Average\ for\ individual\ combination\ (avg) = q * \left(\frac{1}{2}\right) \quad (5.16)$$

Step 4: To arrange the combinations in descending order, equation (5.17) is used.

$$coach\text{-}driver\ combination\ (l[i]) = sortdesc(avg) \quad (5.17)$$

Where l is the list of coach-driver combination averages in descending order and *i* represents the individual values inside the list where, *i* = 1 to *cdc*.

$$final\ list\ (fl[i]) = (os * \mu)/100 + (ac * \alpha)/100 + (ad * \beta)/100 + \frac{l[i] * \rho}{100} \quad (5.18)$$

Equation 5.18 shows the final safety score list (*fl*[i]) for one operator. In this equation, to determine the level of importance of the values, *os*,*ac*,*ad* and $l[i]$, variables (μ,α,β,ρ) are used. By using these variables, the percentage of composition of the *os*, *ac*, *ad* and *l*[i] on the final safety score list *fl*[i] can be determined. For example, weights for these variables can be specified as μ=10,α=5,β=5,ρ=80. This means, operator safety score (*os*) constitutes 10%, average coach score (*ac*) and average driver score (*ad*) constitutes 5% and the final list of coach and driver combination *l*[i] constitutes 80% of the final safety score composition. These compositions are determined based on the DVSA's safe operator guide (DVSA 2016c). Using equation (5.19), possible driver and vehicle combinations under multiple operators who are registered with the coach brokers can be calculated. The final list of operators and their safety scores (*js*) will be listed as,

$$Journey\ Score\ List\ (js) = sortdesc(fl_1[1], fl_2[1], fl_3[1] \dots, fl_\sigma[1]) \quad (5.19)$$

Where, σ denotes the total number of operators registered with a coach broker and js denotes the Journey Score list. Once the *js* is calculated, it can be passed on to the quote engine. (Note: Coaches and drivers who are available for the time of the journey mentioned by the customers only taken into consideration for safety score calculation. Only one set of safest coach and driver combination from each coach operator is made available to the customers. This can avoid getting different driver or coach that are booked for a journey.

Further, the safety scores (os, cs_u and ds_e) can be used to calculate ranks for the operators, their coaches and drivers using the equations 5.20 to 5.22 respectively where σ denotes the total number of operators.

$$Operator\ ranks\ (or) = sortdesc(os_1, os_2, \dots, os_{\sigma}) \qquad (5.20)$$

$$Coach\ ranks\ (cr) = sortdesc(cs_{u1}, cs_{u2}, \dots, cs_{u\sigma}) \qquad (5.21)$$

$$Driver\ ranks\ (dr) = sortdesc(ds_{e1}, ds_{e2}, \dots, ds_{e\sigma}) \qquad (5.22)$$

To rank the best coach and driver combination, equation 5.23 can be used.

$$Coach\ and\ driver\ combination\ rank\ (cdcr) = sortdesc(l[i]_1, l[i]_2, \dots, l[i]_{\sigma}) \qquad (5.23)$$

To summarise the mathematical model, the data obtained from the coach operators are allocated with weight points from which safety scores are calculated (os, cs_u ,ds_e). Based on the safety scores, best coach and driver combinations of a coach operator are calculated ($l[i]$). Using these combinations with operator safety score (os), average coach (ac) and driver (ad) safety scores, final list of best coach and driver combinations for one operator is calculated ($fl[i]$). By repeating ($fl[i]$) for all the coach operators, list of best coach and driver combination of all the operators are calculated (js). Journey score list (js) can be used in stand-alone framework or extended framework (by connecting the *js* values with a quote engine). The safety scores are also utilised to calculate ranks for the coach operators, their coaches and drivers.

5.4.1. *Testing the Model*

The proposed equations were tested for appropriateness and accuracy using real data from two coach operators in Luton in the UK who are registered with the Luton Borough Council. For confidentiality, the names of the operators are anonymised as Operator A and B. Operator A had 3 coaches and 4 drivers. Operator B had 2 coaches and 2 drivers. Table 5.16 shows an example of the data used from operator A and the outcome.

Table 5.16 - Example of data used form operator A

Operator A Data	
Attributes	Parameters
1. Licence Number	xxx2123
2. Roadworthiness OCRS	Amber - 15
3. Traffic OCRS	Green - 5
4. Combined OCRS	Green - 10
Operator A's coach 1 data	
Attributes	Parameters
1. Coach registration number	xx1143
2. MOT	Yes

3. Road tax	Yes
4. Insurance	Yes
5. First use check done?	Yes
6. First use check defects rectified?	N/A
7. Last use check done?	Yes
8. Last use check defects rectified?	N/A
Operator A's driver 1 data	
Attributes	Parameters
1. DBS checked?	Yes
2. In legal driving hours?	Yes
3. Points on driver license	2+ years of experience – 0 points

Weight Allocation:

Using Table 5.15, weight points for the parameters of the operator, their coaches and drivers are allocated. Table 5.17 shows the operator data weight points allocation format prepared using Table 5.15. Using Table 5.16, 5.17, the weight points for the operator A's parameters are assigned as shown in Table 5.18. In a similar way, weight points are allocated for the coaches and drivers as shown in the Tables 5.19 to 5.22. Similarly, weight points for the remaining coaches and drivers of operator A are allocated. Using the same method, weights points for Operator B, their vehicles and drivers are allocated.

Table 5.17 - Operator data weight points allocation

Attribute Number (a_n)	Parameter 1 weight points (p_1) Green	Parameter 2 weight points (p_2) Amber	Parameter 3 weight points (p_3) Red	Parameter 4 weight points (p_4) Grey	Total weight points possible (y_n)	Total weight points obtained (z_n)
ROCRS	*100 to 91*	*90 to 76*	*75 to 1*	*100*	*100*	z_1
TOCRS	*100 to 96*	*95 to 71*	*70 to 1*	*100*	*100*	z_2
COCRS	*100 to 91*	*90 to 76*	*75 to 1*	*100*	*100*	z_3

Table 5.18 - Operator A, parameters weight points

(a_n)	(p_1) Green	(p_2) Amber	(p_3) Red	(p_4) Grey	(y_n)	(z_n)
ROCRS	-	*86*	-	-	*100*	*86*
TOCRS	*96*	-	-	-	*100*	*96*
COCRS	*91*	-	-	-	*100*	*91*

Table 5.19 - Coach data weight points allocation

(a_n)	(p_1) Yes	(p_2) No	(p_b) N/A	(x_n)	(y_n)	(z_n)
MOT	*1*	*0*	-	-	*1*	z_1
Tax	*1*	*0*	-	-	*1*	z_2
Insurance	*1*	*0*	-	-	*1*	z_3

First use check	*1*	*0*	-	-	*1*	z_4
First use check defects Rectified?	*1*	*0*	*1*	*1*	*1*	z_5
Last use check	*1*	*0*	-	-	*1*	z_6
Last use check defects Rectified?	*1*	*0*	*1*	*1*	*1*	z_7

Table 5.20 - Operator A, coach 1 parameters' weight points

(a_n)	(p_1) Yes	(p_2) No	(p_b) N/A	(x_n)	(y_n)	(z_n)
MOT	*1*	-	-	*0*	*1*	*1*
Tax	*1*	-	-	*0*	*1*	*1*
Insurance	*1*	-	-	*0*	*1*	*1*
First use check	*1*	-	-	-	*1*	*1*
First use check defects Rectified?	-	-	*1*	*1*	*1*	*0*
Last use check	*1*	-	-	-	*1*	*1*
Last use check defects Rectified?	*1*	-	-	*0*	*1*	*1*

Table 5.21 - Driver data weight points allocation

(a_n)	(p_1)	(p_2)	(y_n)	(z_n)
DBS	*6.5*	*0*	*6.5*	z_1
Legal driving hours	*6.5*	*0*	*6.5*	z_2
Points on license (1-2exp.)	*12 to 0*	-	*12*	z_3
Points on license (2+ exp.)	*12 to 0*	-	*12*	z_3

Table 5.22 - Operator A, driver 1 parameters' weight points

(a_n)	(p_1)	(p_2)	(y_n)	(z_n)
DBS	*6.5*	*0*	*6.5*	*6.5*
Legal driving hours	*6.5*	*0*	*6.5*	*6.5*
Points on license (1-2exp.)	-	-	*12*	*0*
Points on license (2+ exp.)	*10*	-	*12*	*10*

Safety Score Calculation:

Once the weight allocation is complete, safety scores for operator A, its coaches and drivers can be calculated. Using equation 5.8 and 5.9 the safety scores of the operator and their drivers are calculated and recorded. To obtain the scores for the operator A:

$$Operator\ Safety\ Scoroe\ (os) = \left(\frac{91}{100}\right) \times 100\ \ => \ \ os = 91\%$$

Based on the value of (*os*), Operator A is 91% safe. Individual coach safety score - equation 5.9,

$$Coach\ Safety\ Score\ (cs_1) = \left(\frac{6}{7-1}\right) \times 100\ \ => \ \ cs_1 = 100\%$$

Based on the value of (cs_1), coach 1 of Operator A is 100% safe. Repeating the above equation and by applying the coach attribute weight points for all the coaches, the following values are obtained; cs_2 = 100% cs_3 = 100%. These values indicate that, all the coaches of Operator A are 100% safe.

Average coach safety score - equation 5.11,

$$Average\ Safety\ Score\ of\ Coaches\ (ac) = \left(\frac{1}{3}\right) \times (100 + 100 + 100) => ac = 100\%$$

Based on the value of (*ac*), coaches of Operator A are operating 100% safe. Similarly, to calculate the driver safety scores:

Individual driver safety score - equation 5.10,

$$Driver\ Safety\ Score\ (ds_1) = \left(\frac{23}{37-12}\right) \times 100\ \ => \ \ ds_1 = 92\%$$

Based on the value of (ds_1), Driver 1 of Operator A has achieved a safety score of 92%. Repeating the above equation for all the 4 drivers, ds_2 = 88%; ds_3 = 84% and ds_4 = 80%.

Average driver safety score - equation 5.12,

$$Average\ Safety\ Score\ of\ Drivers\ (ad) = \left(\frac{1}{4}\right) \times (92 + 88 + 84 + 80) => ad = 86\%$$

Based on the value of (ad) Operator A's driver's safety score is 86%. Tables 5.23 and 5.24 show the safety scores of Operator A for their individual coaches and drivers.

Table 5.23 - Coach safety scores

Coach No.	cs_u	Score
1	cs_1	100%
2	cs_2	100%
3	cs_3	100%
u=3		ac = 100%

Table 5.24 - Driver safety scores

Driver No.	ds_e	Score
1	ds_1	92%
2	ds_2	88%
3	ds_3	84%
4	ds_4	80%
e=4		ad = 86%

To find the best possible driver and vehicle combinations following steps are followed,

s*tep 1*: Obtain the total numbers of possible combinations using equation 5.13:

$$cdc = 3 \text{ x } 4 = 12.$$

This means, there are 12 possible driver-vehicle combinations in total for Operator A.

step 2: Find the sample space, using equation 5.14, Sample Space, Ω = {(100,92), (100,88), (100,84), (100,80), (100,92), (100,88), (100,84), (100,80), (100,92), (100,88), (100,84), (100,80)}.

step 3: Find the total number of combinations using equation 5.15,

q = {(100+92), (100+88), (100+84), (100+80), (100+92), (100+88), (100+84), (100+80), (100+92), (100+88), (100+84), (100+80)}.

Using equation 5.16:

avg = {192, 188, 184, 180, 192, 188, 184, 180, 192, 188, 184,180} * (1/2) = > avg = {96, 94, 92, 90, 96, 94, 92, 90, 96, 94, 92, 90}

step 4: Find the combinations in descending order using equation 5.17:

$l[i]$ = sort-desc({96,94,92,90,96,94,92,90,96,94,92,90})

$l[i]$ = {96,96,96,94,94,94,92,92,92,90,90,90}

For the final safety score list using equation 5.18:

$fl[1]$ = (91*10)/100 + (100*5)/100 + (86*5)/100 + (96*80)/100

$fl[1]$ = 95.2%

Where, μ = 10, α = 5, β = 5, ρ = 80 and i = 1 to 12. $fl_1[i]$ is the final safety score combination list for operator A. $fl_1[i]$ = {95.2, 95.2, 95.2, 93.6, 93.6, 93.6, 92, 92, 92, 90.4, 90.4, 90.4}. Table 5.25 shows the mapping of average values and sums for the coach and driver combinations (i.e complete list of all the final values for Operator A).

Table 5.25 - Mapping of average values with vehicle and driver combinations for Operator A

l[i]	cs_u	ds_e	Sum	Average	*fl[i]*
l[1]	cs_1	ds_1	192	96	95.2%
l[2]	cs_2	ds_1	192	96	95.2%
l[3]	cs_3	ds_1	192	96	95.2%
l[4]	cs_2	ds_2	188	94	93.6%
l[5]	cs_3	ds_2	188	94	93.6%
l[6]	cs_1	ds_2	188	94	93.6%
l[7]	cs_3	ds_3	184	92	92%
l[8]	cs_1	ds_3	184	92	92%
l[9]	cs_2	ds_3	184	92	92%
l[10]	cs_1	ds_4	180	90	90.4%
l[11]	cs_2	ds_4	180	90	90.4%
l[12]	cs_3	ds_4	180	90	90.4%

The same approach can be used to calculate the safety scores for Operator B. Table 5.26 shows the mapping of average values with vehicle and driver combinations for Operator B.

Table 5.26 - Mapping of average values with vehicle and driver combinations for Operator B

l[i]	cs_u	ds_e	Sum	Average	*fl[i]*
l[1]	cs_1	ds_2	196	98	96.4%
l[2]	cs_2	ds_2	196	98	96.4%
l[3]	cs_1	ds_1	180	90	90%
l[4]	cs_2	ds_1	180	90	90%

equation 5.19 can then be used to sort in descending order, the final list of safest coach and driver combinations for both the operators.

$$js = (96.4, 95.2)$$

The values of *js* can be passed on to a quote engine of a coach broker where the above two combinations will be listed with the price specified by the operator. Equations 5.20 to 5.22 are used to find the ranks of coach operators, their coaches and vehicles respectively.

Operator rank - equation 5.20:

$$Operator\ ranks\ (or) = sortdesc(91{,}86)$$

Coach rank – equation 5.21:

$$Coach\ ranks\ (cr) = sortdesc(100{,}100{,}100{,}100{,}100)$$

Driver rank – equation (5.22),

$$Driver\ ranks\ (dr) = sortdesc(96{,}92{,}90{,}88{,}84{,}80)$$

Best coach and driver combination – equation 5.23:

$$Coach\ and\ driver\ combination\ rank\ (cdcr) = sortdesc(98{,}98{,}96{,}96{,}96{,}94{,}94{,}94{,}92{,}92{,}92{,}90{,}90{,}90{,}90{,}90)$$

The mathematical testing of the model confirmed that it works well and safety scores calculated for typical journeys were accurate when compared with scores obtained from authorised UK Government sources such as DVSA, or DVLA (DVSA 2016b, DVLA 2017b).

5.5 The Importance of the Safety Transport Framework

The existing literature which addressed the safety of children travelling in coaches/buses were focused on the route planning (Miranda et al. 2018), tracking (Takalikar et al. 2018) and other aspects (see section 2.2) of the coach travel and failed to address the problem of coach operator non-compliance which could jeopardise the entire school journey. By holistically analysing the safety of coach-based school transport in the UK (see section 3.4), related issues and requirements were identified (see section 4.5). From this, significant issues and requirements were isolated and addressed through the proposed safety transport framework (see section 5.3). In the safety transport framework, the reason to create safety scores is to encapsulate all the safety elements of a coach travel into a single score. By doing this, there is no need to verify an operator, a coach, or a driver separately. The existing safety-scoring model developed by the UK government doesn't represent the safety of an entire journey (DVSA 2016b). Moreover, the existing government guidelines and frameworks didn't address the problem of latency in updating the OCRS in the system (Department for Education 2014). Latency in updating the government databases can be avoided using this safety transport framework, as the data gathered from the operators will be updated every day.

To verify that the safety transport framework addressed the critical issues and requirements identified in section 4.5 Table 5.27 is created. The table shows the significant issues and how the safety transport framework can address the issues.

Table 5.27 - How the safety transport framework solves the significant issues

No.	**Significant Issues/Requirements**	**How the safety transport framework solve it?**

1	Unaware of driver and coach conditions	The framework will bridge the knowledge gap between the stakeholders by presenting the operator safety scores to the customers (schools/parents) when they try to book a coach for a journey.
2	Inexperienced driver (driver error)	Safety score for each driver is calculated based on the driver related attributes and parameters (see section 5.3.1.3). So, the accidents occurring due to driver error (DfT - Ras50005 2017) can be reduced by selecting the right driver.
3	Vehicle out of control (vehicle error)	Safety score for each coach is calculated based on the coach related attributes (see section 5.3.1.2). Accidents occurring due to coach error (DfT - Ras50005 2017) can be reduced by selecting the right coach.
4	Driver Fatigue	One of the attributes for calculating the driver safety score is the driver's driving hour violation identified through the analysis of Tachograph history (see section 5.3.2.2). Using the driver who has low violation in driving hours may possibly reduce accidents occurring due to driver fatigue (VOSA 2011) caused by irregular rest.
5	Information about driver's and coach's status	Similar to Issue No.1 above, parents and schools requested to check the driver's and coach's status before the journey to validate them (i.e) to make sure they are safe for the journey.
6	Schools need to check the vehicle's and the driver's documents for safety reasons	Similar to Issue No.1 above, parents requested the schools to check the driver's and vehicle's documents for a safe journey. Both, Requirement No.5 and No.6 can be rectified through this framework.

5.6 Chapter Summary

This chapter discussed the proposed safety transport framework in detail. The design process behind the framework was discussed first, followed by the steps used in the framework. The framework comprises of 5 steps: data acquisition, data verification, data weight point allocation, safety score calculation and intelligent data analysis.

Each step was discussed in detail. The safety transport framework was modelled mathematically to prove their concepts. To test performance, real data from two coach operators were used. The testing results proved that the framework worked as expected. Chapter 6 discusses a prototype which was developed to utilise the framework in the full context and also the evaluation of the prototype and the framework.

Chapter 6
Framework and Prototype Evaluation

6.1. Introduction

This chapter discusses the prototyping of the framework and the evaluation of both the prototype and the framework. The evaluations were carried out through the involvement of stakeholders of coach-based school transport across the UK.

6.2. Prototype Development

The aim of the prototype is to implement the safety transport framework using the mathematical equations, which is discussed in section 5.4. The safety framework is prototyped into a web application which is created using Personal Home Page (PHP) and hosted through a windows web development environment – wamp server (Bourdon 2018). Figure 6.1 shows a screenshot of Step 1 of the safety framework prototype, data acquisition, where the operator's data is collected through a user interface. Step 2, as is discussed in section 5.3.2, is subject to government approval thus the values are verified locally. Step 3, 5 and 5 are background process in which the weights are pre-allocated, safety scores are calculated, and safety recommendations are prepared. Figure 6.2 shows the results screen of the prototype after submitting the coach operator data. The best operator and driver combination is identified, and safety recommendations are provided to the operator. Figure 6.3 shows the output of the safety transport framework prototype if it is connected to a quote engine of a coach broker where quotes from different operators gathered along with their safety scores and presented to the customers. This can help the customers to make an informed decision when booking coaches for school trips.

Figure 6.4 shows the screenshot of the enhanced view of the intelligent system for safety recommendation (Step 5) in which operator data is analysed to provide a better view of their fleet. It also provides operators with recommendations to improve their fleet safety level. (Note: Figures 6.3 and 6.4 are modified to give a better view of the output of the safety transport framework).

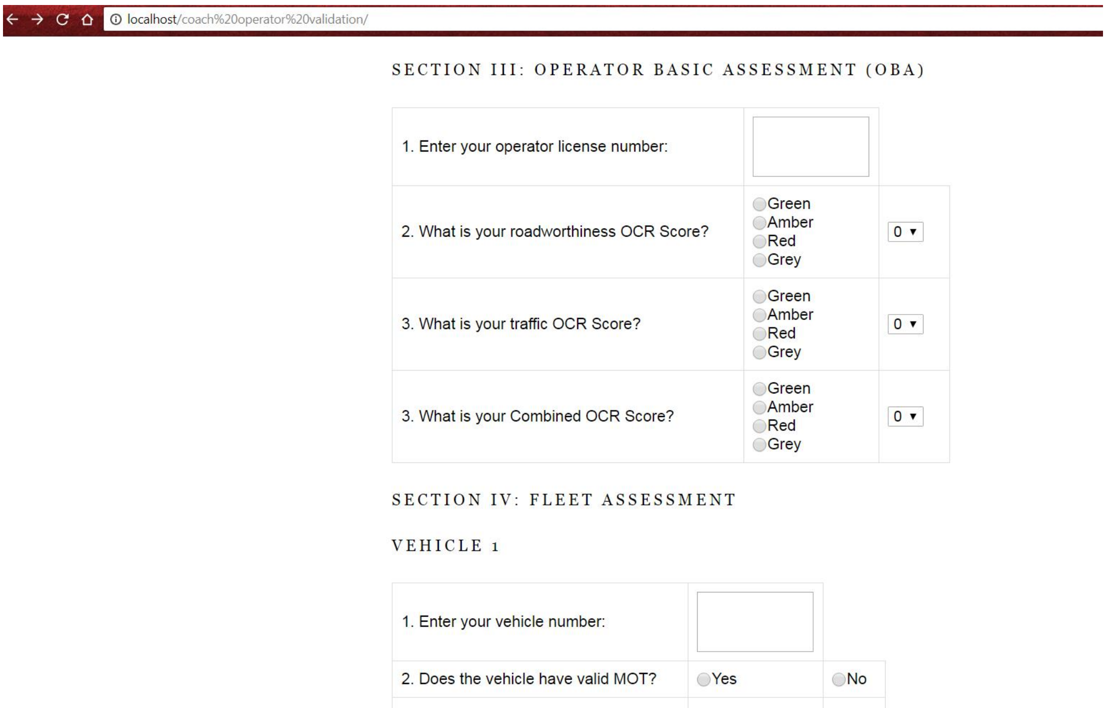
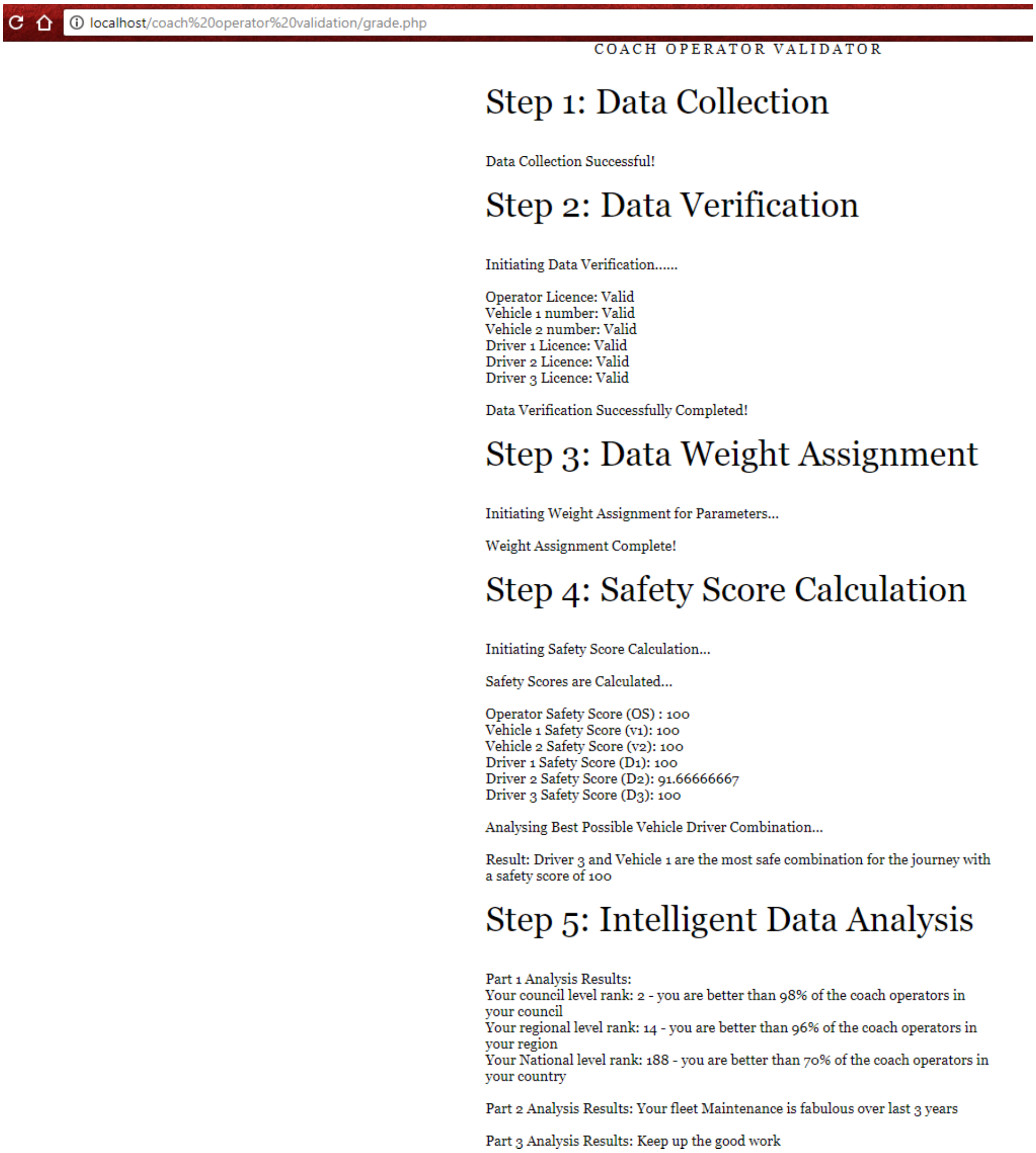


Figure 6.1 - Operator data acquisition


localhost/coach%20operator%20validation/grade.php

COACH OPERATOR VALIDATOR

Step 1: Data Collection

Data Collection Successful!

Step 2: Data Verification

Initiating Data Verification......

Operator Licence: Valid
Vehicle 1 number: Valid
Vehicle 2 number: Valid
Driver 1 Licence: Valid
Driver 2 Licence: Valid
Driver 3 Licence: Valid

Data Verification Successfully Completed!

Step 3: Data Weight Assignment

Initiating Weight Assignment for Parameters...

Weight Assignment Complete!

Step 4: Safety Score Calculation

Initiating Safety Score Calculation...

Safety Scores are Calculated...

Operator Safety Score (OS) : 100
Vehicle 1 Safety Score (v1): 100
Vehicle 2 Safety Score (v2): 100
Driver 1 Safety Score (D1): 100
Driver 2 Safety Score (D2): 91.66666667
Driver 3 Safety Score (D3): 100

Analysing Best Possible Vehicle Driver Combination...

Result: Driver 3 and Vehicle 1 are the most safe combination for the journey with a safety score of 100

Step 5: Intelligent Data Analysis

Part 1 Analysis Results:
Your council level rank: 2 - you are better than 98% of the coach operators in your council
Your regional level rank: 14 - you are better than 96% of the coach operators in your region
Your National level rank: 188 - you are better than 70% of the coach operators in your country

Part 2 Analysis Results: Your fleet Maintenance is fabulous over last 3 years

Part 3 Analysis Results: Keep up the good work

Figure 6.2 - Coach operator validation results

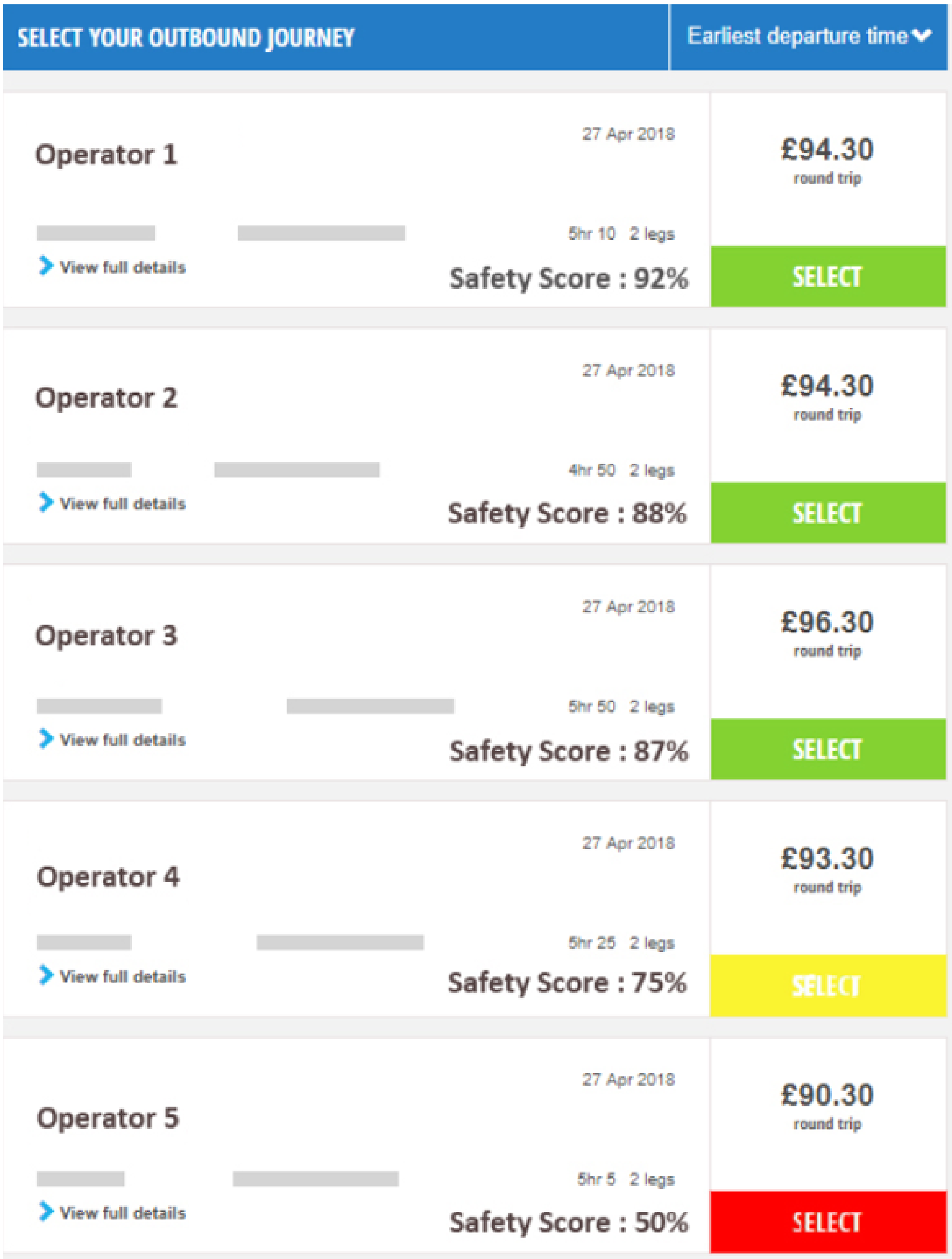


Figure 6.3 - Coach operators quotes sorted based on their safety scores

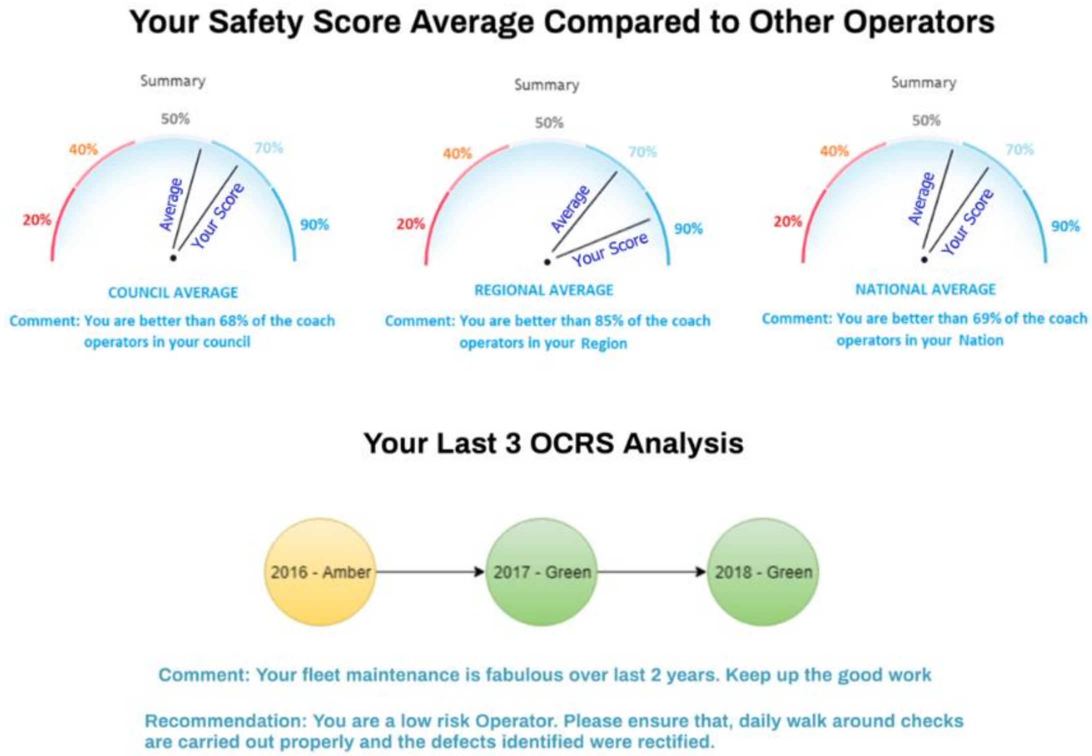


Figure 6.4 – Safety level of the operators with safety recommendations

6.3. Framework and Prototype Evaluation

6.3.1 Evaluation Objectives and Procedure

The objective of the evaluation is to test the appropriateness, suitability and overall effectiveness of the safety transport framework and its prototype in respect to coach-based school transport.

A web-based survey tool (google forms) supported by an online questionnaire was used to implement this evaluation. Stakeholders were provided with the description and diagrams of the framework and screenshots in respect to the prototype, followed by a set of key questions related to them. This approach was chosen as an evaluation method which was used by a number of researches (Anund et al. 2014, Falkmer et al. 2014).

Prior to the collection of the data, a pilot test of the questionnaire was administered to 2 coach operators to identify errors, avoid wrong design and thereby predicting possible problems. Once, the corrections were made to the questions based on the feedback from the participants, the survey link was shared with the stakeholders. In addition to the website, the survey was also conducted by visiting schools in Luton and surrounding areas to collect feedback from parents and Headmasters. In total, 112 responses were received from different stakeholders which include, 70 parents/school Headmasters, 29 coach operators and 13 council transport officers/road safety analysts. Figure 6.5 shows the composition of the participants and their responsibilities. The outcome of the evaluation is discussed in the section 6.3.2.

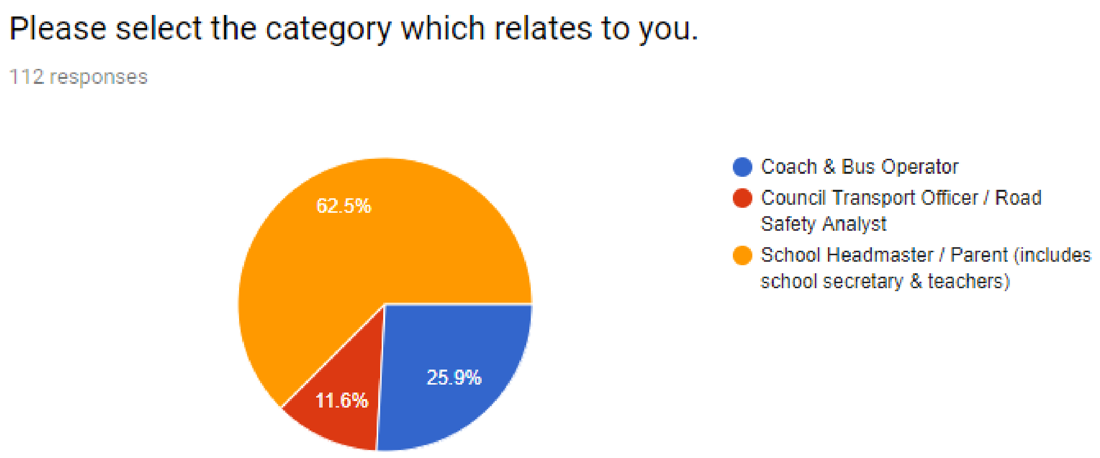


Figure 6.5 – Question and responses of different stakeholders

6.3.2 Results Interpretation

6.3.2.1 Framework Evaluation Results

Cross-tabulation method proposed by (Hellevik 1988) was used to analyse the evaluation results. For the complete list of responses, please refer Appendix 4. When the stakeholders were asked, “Do you think the approach taken by the framework consider suitable and relevant information for validating the safety?” all the school parents/Headmasters and town council transport officers/road safety analysts answered “Yes”. In total 96.6% of the coach operators answered “Yes” whereas the remaining 3.4% of the operators said “No”.

To gather the stakeholder views about the proposed framework, stakeholders were asked, “Do you think the structure of the framework is suitable for coach journey validator to qualify an operator/driver?”. All the respondents answered “Yes” (Excluding coach operators). Also, 96.4% of the coach operators answered “Yes” and the remaining 3.6% of the operators said “No”. This gives an indication that the steps used in the safety framework are appropriate for its purpose.

To check the adequateness of the data collected in the framework, stakeholders were questioned, “Do you think sufficient data is collected in Step 1 to validate the coach operators, vehicles and drivers?” All the participants answered “Yes” (the response of coach operators are not included. Also, 96.6% of the coach operators answered “Yes” whereas the remaining 3.4% of the operators said “No”. This question is crucial as the data gathered plays an important role in validating the coach operators for a school journey. Stakeholder responses prove that the data collected in the safety transport framework is sufficient for its purpose.

To check the authenticity of the data collected, stakeholders were asked, “Does the approach taken in Step 2 to check the authenticity of the checks carried out for drivers and coaches safety appropriate?” All the school parents/Headmasters, 92.3% of town council transport officers/road safety analysts and 96.6% of coach operators answered “Yes” and the remaining answered “No”.

To get the stakeholders views on the fairness of the weight allocation, stakeholders were asked, “In Step 3, do you think it is appropriate to allocate lesser consideration to different attributes as some attributes have greater significance than others?" All respondents answered "Yes" except coach operators where as 96.6% of coach operators answered, "Yes" and the remaining 3.4% answered "No". The weight disbursement method was designed to let the managers of the safety framework modify the weight disbursement value at any time, which allows them to customise the framework to suit the operators based on the local circumstances.

To check the correctness of the safety score calculation methods, the stakeholders were questioned, "In Step 4, do you think the safety score calculation method is appropriate and provides the relevant safety scores?". All the respondents except coach operators answered "Yes". Also, 96.6% of coach operators answered "Yes" and the remaining 3.4% answered "No".

To check the usefulness of the safety recommender for coach operators, they were asked, "In Step 5, do you think the Intelligent system provides relevant and appropriate recommendations to coach operators to improve their safety?". In total, 96.6% of coach operators answered "Yes" and the remaining answered "No" which shows that the majority of the coach operators found the intelligent system helpful (Note: Coach operators were only asked this question as it is not relevant to other stakeholders).

To check the appropriateness of the safety score calculation, coach operators were asked, "Do you think the safety score calculated can help to raise the operation safety standards of operators, vehicles and drivers?" 89.7% of coach operators answered "Yes" and the remaining answered "No" presenting that most of the operators think the safety scores are calculated based on the appropriate government standards.

To gather the views of stakeholders about the impact of the prototype and framework, stakeholders were asked, "Do you think this framework, will improve safety of school children transport by coaches/buses?" all the respondents except coach operators answered "Yes" whereas 89.7% of coach operators answered "Yes".

6.3.2.2 Prototype Evaluation

To gather the views about the capability of the prototype, stakeholders were questioned, "Do you think the prototype clearly illustrates the capability of the framework?" all respondents answered "Yes" except coach operators whereas 96.6% of coach operators answered, "Yes" and the remaining 3.4% answered "No".

To test the preference of the stakeholders with respect to Figure 6.3, whether they are choosing the safe operator over a cheap price operator or compromise the safety for the price, the stakeholders were asked separately, which coach operator they would choose for a journey. In total, 92.9% of parents and school Headmasters and all the town council transport officers selected the Operator 1 with highest safety score. 7.1% of the parents and school Headmasters selected Operator 2 as shown in Figure 6.6. None of the participants selected operator 3,4 or 5, even though their prices are low compared to operator 1 and 2. This shows that none of the participants prefers a cheaper operator. To get stakeholder responses on the overall effectiveness of the safety transport framework, they were provided with a scale format to answer the question: "Overall, how effective do you think this framework is for validating coach operators for school journeys?" Figure 6.7 shows the responses on overall effectiveness. In total 87% of the school Headmasters/parents, 65% of the coach operators and 77% of the council transport officers/road safety analysts responded that the framework is extremely effective. 10% of the school Headmasters/parents, 24% of the coach operators and 15% of the council transport officers/road safety analysts responded that the framework is quite effective. The remaining indicated moderately effective. This shows that the majority of the stakeholders found the framework to be effective and can improve the safety of children travelling through coaches in the UK.

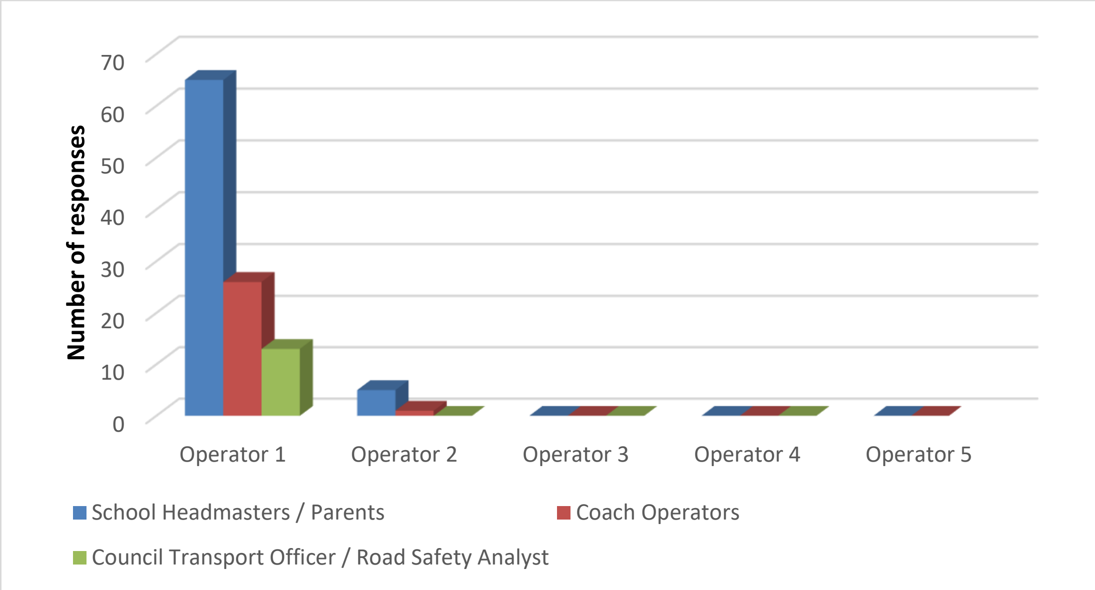


Figure 6.6 - Stakeholder overall responses for selection of safe operators

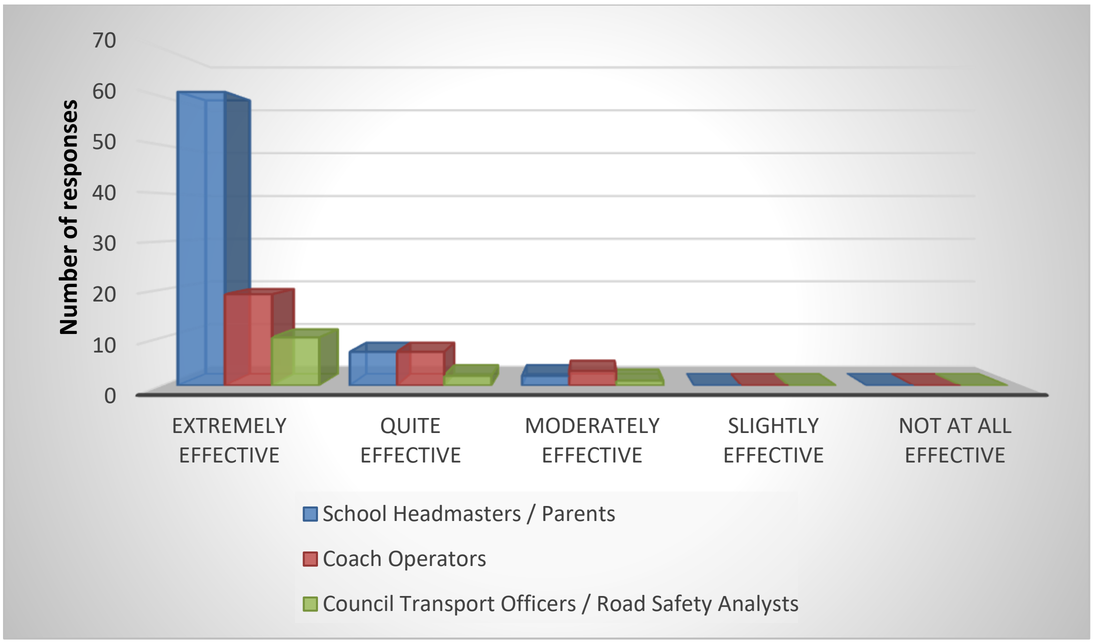


Figure 6.7 - Stakeholder responses for the overall effectiveness of the framework and prototype

6.4. Applying the framework to past accidents

The framework and the prototype were evaluated with the involvement of the stakeholders as shown in the Figure 6.7. To verify whether the coach accidents happened in the past could have been avoided if this framework was used, the contributory factors for those accidents are cross checked with the framework as shown in the table 6.1.

Table 6.1 – Applying the framework for the existing accidents' contributory factors

No.	**Causes of accidents in the past**	**Would the application of the safety transport framework avoided the past accidents?**
1	Accidents occurred due to vehicle out of control (vehicle error)	This framework considers the road worthiness of a coach and the safety check compliance of the coach operators. As the safety score for each coach is calculated based on the coach related attributes (see section 5.3.1.2), the coach with highest safety score would have been suggested to schools or parents. It is more likely that schools or parents would have chosen the coach with the highest safety score. By doing this, it is most likely that the accidents occurred due to coach error (DfT - Ras50005 2017) would have been avoided.
2	Accidents occurred due to Inexperienced driver (driver error)	Driver licence penalty point system separates drivers into two categories, which is based on their experience (see table 5.4). As the calculation of the safety scores for each driver is based on the driver's related attributes and parameters, which includes the number of penalty points, (see section 5.3.1.3) the driver with highest safety score would have been suggested to the schools or parents. It is more likely that the schools or parents would have chosen the driver with highest safety score. By doing this, it is more likely that the accident occurred due to driver error (DfT - Ras50005 2017) could have been avoided.
3	Accidents occurred due to driver fatigue	One of the attributes for calculating the driver safety score is the driver's driving hour violation identified through the analysis of Tachograph history (see

		section 5.3.2.2). This framework by using this information can show compliance to the government guidelines or its violation. This would have helped schools and parents to choose the driver who had low violation in driving hours which could have possibly reduced the accidents occurred due to driver fatigue (VOSA 2011) caused by irregular rest.

To evaluate the framework further, a coach accident happened in Belgium is considered (Espinoza 2015). A coach driver has been killed and his assistant and two children seriously injured after a coach carrying pupils and staff from private school in Essex crashed in Belgium. The bus driver reportedly lost control of his vehicle and hit the pillar of a bridge (vehicle error). This occurred due to an improper walk around check the driver had carried out before embarking the return journey (driver error) (Espinoza 2015, DfT - Ras50005 2017). This accident would have probably been avoided if the schools had chosen a coach with proper maintenance record and a driver with good experience. By using the proposed framework, it will be more likely that this kind of accident can be avoided.

6.5. Limitations of the Safety Transport Framework

Even though the framework has achieved its intended purpose, it has a few limitations which are explained below.

1. Difficulty in data acquisition – The data collected in Step 1 (see section 5.3.1.1) is confidential to coach operators and it is hard to assume that all the coach operators (especially the ones with low OCRS scores) will be willing to provide the data. This limitation is addressed through the safety recommendation framework (see section 5.3.5) which helps the operators to improve their safety scores.

2. Data verification – Verification of the operator's data is done locally. This means that, the data is not cross-checked between the DVSA and DVLA. Because the reason being that approval from the government takes time to give access to the DVSA and DVLA. This limitation is addressed by manually verifying the operator data with official documents which supports them (OCRS reports, vehicle and driver logs). This may be automated once the official access to the authentic sources can be obtained.
3. It is impossible to completely guarantee that all the journeys will be safe. The safety transport framework attempts to maximise the safety by validating all the essential safety aspects of a coach travel. However, the validation is limited to operators who agreed to provide their data and the framework does not include external factors like other people driving around the coach, weather and road conditions, which may affect the safety of a journey.

6.6. Chapter Summary

The safety transport framework was prototyped in the form of a web application. Both the framework and the prototype were evaluated using relevant stakeholders. The analysis of the results provides clear evidence that this framework is very effective. The real-time test has so far confirmed the capability of the framework, which may be used for wider applications, possibly globally after some modifications to it.

Chapter 7
Conclusion and Future Work

Safety in school transport is a critical issue which involves children who are the most vulnerable users of it. Safety in hired coaches by schools in the UK in particular, is a less investigated area, compared to the other modes of transport to school. 1218 children were injured in 381 coach crashes between 2005 and 2016. Driver errors or technical faults in vehicles were the most commonly reported contributory factors for coach accidents which happens due to operator non-compliance. In the last year alone, 78 coach operators' licenses have been revoked due to non-compliance with the government regulations. Though the government has strict safety regulations, accidents are still happening. Limited research has been carried out on coach-based school transport. The existing literature so far focused on the different aspects of school transport but didn't address non-compliance problem. The intention of the thesis was to explore the safety level of coach-based school transport in the UK in-terms of coach operations and safety compliance. It was also to propose the necessary safety solutions to improve the safety of school children travelling through coaches.

Seven objectives were formed (see section 1.4) based on the research questions (see section 1.2). These objectives were achieved throughout the thesis, which is summarised as follow:

Relevant literature was analysed to investigate the safety of coach-based school journeys in the UK. The literature on the safety-related aspects of coach/bus-based school transport was reviewed. An in-depth analysis of safety of children travelling by hired coaches was carried out. History of coach accidents involving children and their contributory factors were analysed. Government policies and guidelines to reduce these accidents were reviewed. Analysis of the traffic commissioners' reports was provided. It became apparent the research on the safety of children travelling on hired coaches/buses was not as widely investigated compared to the other modes of transport to school in the UK. The investigation highlighted that the major contributory factors for the accidents related to vehicle error and driver error. Vehicle error and driver error occurs due to improper maintenance and operator non-compliance with the safety regulations. The UK government have strict regulations in place for the operators to maintain their fleet safety level. But, according to traffic commissioner's reports, some coach operators are not compliant with the regulations and operator non-compliance still exist. Traffic enforcement officers try to make sure that all the coach operators are compliant with the safety regulations and revoke the licences of the coach operators who failed comply with the safety regulations. This problem is not addressed in any academic literature so far. Most of the available evidence are in the form of grey literature (government reports).

To further investigate the safety of children in coach trips in the UK in terms of coach operations and safety compliance, sequential exploratory mixed methodology was adapted. Two surveys were conducted as part of the sequential exploratory mixed methodology. The survey questions were focused on the safety aspects of a coach journey. School headmasters, parents, coach operators, coach drivers, town council transport officers and road safety analysts were participated in the survey. Survey results identified significant safety issues related to coach-based school transport. The most significant safety issue identified is the unawareness of the stakeholder of drivers and vehicles conditions before and during school trips. Parents trusts the schools that they will ensure the safety of children travelling by hired coaches. Schools trust coach operators that they ensure the coach provided for school journeys are fit for purpose.

But based on the traffic commissioners' reports, it is hard to assume that the coach operators are compliant with the safety regulations all the time. To address these issues a safety transport framework was proposed. The framework collects the coach operators' data, validates it and provides safety scores to the users (school headmasters or parents) prior to booking a coach. This helps the users to select the safest coach and driver available thereby increasing the safety of a school journey. The proposed framework also analyses the coach operator's data and provide safety recommendations to the coach operators to increase their fleet's safety. As part of the proposed framework, limitations in the existing government safety scoring system were identified and suggestions are made for rectifying part of the scoring system (see section 5.3.2.2). A prototype was designed to test the framework, which clearly illustrated the proof of concept. To test the appropriateness and accuracy of the framework, real data from two coach operators were used as a pilot. The testing results proved that the framework worked as expected. The prototype and the framework were evaluated using relevant practitioners and stakeholders and the outcome was discussed. The analysis of the evaluation provides a clear indication of the positive response received supporting of this framework. The approach used in this framework, can be extended to wider applications.

7.1. Contributions

This thesis provided the following contribution to knowledge:

1. ***Coach Travel Safety Analysis Matrix (CTSAM):*** A tool created to analyse the safety of coach-based school transport in the UK (Ramachandran et al. 2018a).
2. ***Safety transport framework:*** A unique safety transport framework, which can be used to validate coach operators, coaches and drivers at the time of booking

a coach is proposed. The framework enables schools to select a safe operator. (Ramachandran et al. 2017, Ramachandran et al. 2017a).

3. ***Intelligent system for safety recommendation:*** An intelligent system that provides safety recommendations to coach operators that enables coach operators to improve the safety of their fleets is proposed (Ramachandran et al. 2018b).

7.2. Future Research Directions

This thesis discussed important safety issues and requirements of stakeholders for coach-based school transport in the UK (see Chapter 4) and responded by providing a framework. There were a number of issues which were outside the scope of this research which can be considered for future work. They include,

1. A cost-effective GPS based tracking of coach and children can provide additional travelling information to parents. GPS based tracking is one of the major requirement of the stakeholders. Even though there are GPS based tracking for coaches already exist (Mulla 2015, Takalikar et al. 2018), cost of implementing it is still high. The possible solution for this can be mobile application-based GPS tracking. Exploring cost-effective tracking methods can rectify this requirement.

2. Use of bus escorts is another approach to improve safety by monitoring and instructing children whilst the coach is moving. But, cost of employing a bus escort is high and some stakeholders suggested to use CCTV for this purpose. Researching in to cost effective ways of monitoring children during the journey will be a possible research direction.

3. Application of machine learning in the safety recommender tool can further improve its accuracy. Intelligent data analysis and recommendation model (see section 5.3.5) only considered the operational issues responsible for the operator non-compliance. However, the psychological and practical issues (Gertler 2011) involved in operator non-compliance must be studied to provide more relevant recommendations to improve coach operator's fleet safety. Also, using machine learning algorithms (Nasrabadi 2007) to predict operator's recommendations can be another research direction.

4. By storing the data output from the "safety transport framework" using Blockchain, the customers (schools/parents) and coach operators can be connected without involving coach brokers.

5. There is a potential opportunity to expand the application of the proposed framework to other areas such as coach tourism which require compliance and compliance-based validation.

References

Abulhassan, Y., Davis, J., Sesek, R., Schall, M., and Gallagher, S., 2017. Evacuating a rolled-over school bus: Considerations for young evacuees. *Safety Science* [online], (July), 0–1. Available from: http://dx.doi.org/10.1016/j.ssci.2017.07.017.

Aigner-Breuss, E., Pilgerstorfer, M., Anund, A., Dukic, T., Chalkia, E., Ferrarini, C., Montanari, R., Wacowska, J., Jankowska, D., Diederichs, F., and Pauzie, A., 2010. Comparison and analysis of user and stakeholder needs across different countries, (September).

Al-lawati, A., Al-jahdhami, S., Al-belushi, A., Al-adawi, D., Awadalla, M., and Al-abri, D., 2015. RFID-based System for School Children Transportation Safety Enhancement, 1–4.

Albertsson, P., Björnstig, U., and Falkmer, T., 2003. The Haddon matrix, a tool for investigating severe bus and coach crashes. *International Journal of Disaster Medicine* [online], 1:2, s. 10, 109–119. Available from: http://urn.kb.se/resolve?urn=urn:nbn:se:hj:diva-6282%5Cnhttp://urn.kb.se/resolve?urn=urn:nbn:se:umu:diva-6560%5Cnhttp://dx.doi.org/10.1080/15031430310035272.

Anna, A., Chalkia, E., Nilsson, L., Diederichs, F., Ferrarini, C., Montanari, R., Strand, L., Aigner-Breuss, E., Jankowska, D., and Wacowskka-Slezak, J., 2012. Integrated system for safe transportation of children to school Collaborative project 233967 Final report, 1–60.

Anund, A. and Dukic, T., 2011. From user wishes to system architecture safety for children going to and from school by bus. *2011 11th International Conference on ITS Telecommunications, ITST 2011*, 327–331.

Anund, A., Dukic, T., Börsbo, B., and Falkmer, T., 2010. Piloting smart safe school bus: exploration of security gains from implementation of a driver support system, additional technical equipment and intelligent bus stops. *European Transport Research Review* [online], 2 (3), 157–163. Available from: http://www.springerlink.com/index/10.1007/s12544-010-0035-0.

Anund, A., Dukic, T., Thornthwaite, S., and Falkmer, T., 2011. Is European school transport safe?—The need for a "door-to-door" perspective. *European Transport Research Review* [online], 3 (2), 75–83. Available from: http://www.springerlink.com/index/10.1007/s12544-011-0052-7.

Anund, A., Viklund, Å., and Appeltofft, K., 2014. School Transportation and its regulation – an outcome from the EU project SAFEWAY2SCHOOL.

Assi, K. J., Nahiduzzaman, K. M., Ratrout, N. T., and Aldosary, A. S., 2018. Mode choice behavior of high school goers: Evaluating logistic regression and MLP neural networks. *Case Studies on Transport Policy* [online], 6 (2), 225–230. Available from: https://doi.org/10.1016/j.cstp.2018.04.006.

Awuahaddor, J., Amponsah, S. K., Annan, J., and Sebil, C., 2013. School Bus Routing A Case Study of Wood Bridge School Complex, Sekondi-Takoradi, Ghana.pdf, (December), 26–36.

BBC, 2017a. *What are the different types of schools?* [online]. BBC website. Available from: https://www.bbc.co.uk/newsround/37696598 [Accessed 27 Jun 2018].

BBC, 2017b. Driver dies after school bus crash in Aberdeenshire. *BBC website* [online], 11 December 2017. Available from: https://www.bbc.co.uk/news/uk-scotland-north-east-orkney-shetland-42363808.

BBC, 2018. Twenty hurt in school bus lorry crash on Dunstable road. *BBC website* [online], 18 May 2018. Available from: https://www.bbc.co.uk/news/uk-england-northamptonshire-44168523.

Beck, L. F. and Nguyen, D. D., 2017a. School transportation mode, by distance between home and school, United States, ConsumerStyles 2012. *Journal of Safety Research*, 62, 245–251.

Beck, L. F. and Nguyen, D. D., 2017b. School transportation mode, by distance between home and school, United States, ConsumerStyles 2012. *Journal of Safety Research* [online], 62, 245–251. Available from: http://dx.doi.org/10.1016/j.jsr.2017.04.001.

Berman, E., 2017. An Exploratory Sequential Mixed Methods Approach to Understanding Researchers' Data Management Practices at UVM: Integrated Findings to Develop Research Data Services. *Journal of eScience Librarianship* [online], 6 (1), e1104. Available from: http://escholarship.umassmed.edu/jeslib/vol6/iss1/7/.

Bernard, R., 2010. *Fundamentals of BIOSTATISTICS Seventh Edition*. Cengage Learning.

Bishop, R. and Campbell, S., 2016. France coach crash: Two British school kids critically injured and 13 hurt in motorway accident. *mirror.co.uk* [online], 23 July 2016. Available from: http://www.mirror.co.uk/news/world-news/france-coach-crash-two-british-8477595.

Björsell, K. and Hedman, J., 2018. Future impacts of self-driving vehicles: A case study on the supply chain of e-commerce to identify important factors for the transport administrators of Sweden.

Bogl, M., Doerner, K. F., and Sophie, N. P., 2015. The School Bus Routing and Scheduling Problem with Transfers. *Networks*, 47 (1), 26–36.

Bourdon, R., 2018. *Wamp Server - Windows web development environment* [online]. SourceForge. Available from: http://www.wampserver.com/en/ [Accessed 17 Sep 2018].

BRACA, J., BRAMEL, J., POSNER, B., and SIMCHI-LEVI, D., 1997. A computerized approach to the New York Cityschool bus routing problem. *IIE Transactions* [online], 29 (8), 693–702. Available from: http://link.springer.com/10.1023/A:1018526202990 [Accessed 2 Dec 2016].

Brannen, J., 2017. *Mixing methods: Qualitative and quantitative research*. Routledge.

Braun, V. and Clarke, V., 2006. Using thematic analysis in psychology Thematic. *Qualitative Research in Psychology*, 3, 77–101.

Bull, M. J., Agran, P., Gardner, H. G., Laraque, D., Pollack, S. H., Smith, G. A., Spivak, H. R., Tenenbein, M., Brenner, R. A., Bryn, S., Neverman, C., Schieber, R. A., Stanwick, R., Tinsworth, D., Garcia, V., Tanz, R. R., Katcher, M. L., Pickering, L. K., and Newland, H., 2018. School bus transportation of children with special health care needs. *Pediatrics*, 108 (2 II).

Caceres, H., Batta, R., and He, Q., 2017. School Bus Routing with Stochastic Demand

and Duration Constraints. *Transportation Science* [online], 51 (4), 1349–1364. Available from: https://doi.org/10.1287/trsc.2016.0721.

Chen, X., Kong, Y., Dang, L., Hou, Y., and Ye, X., 2015. Exact and Metaheuristic Approaches for a Bi-Objective School Bus Scheduling Problem. *Plos One* [online], 10 (7), e0132600. Available from: http://dx.plos.org/10.1371/journal.pone.0132600.

Clarke, V. and Braun, V., 2013. Teaching thematic analysis: Over- coming challenges and developing strategies for effective learning. *The Psychologist* [online], 26 (2), 120–123. Available from: http://eprints.uwe.ac.uk/21155.

Colley, M. E., 2017. Gender Differences in the Commute to School and Work through Time and Space in the Greater Toronto and Hamilton Area , Gender Differences in the Commute to School and Work through Time and Space in the Greater Toronto and Hamilton Area , Canada. *In*: *Transportation Research Board 96th Annual Meeting*.

Collins, P., Al-Nakeeb, Y., and Lyons, M., 2015. Tracking the Commute Home From School Utilising GPS and Heart Rate Monitoring: Establishing the Contribution to Free-Living Physical Activity. *Journal of physical activity & ...* [online], 12 (December 2015), 155–162. Available from: http://europepmc.org/abstract/MED/24762330.

Commissioners, T., 2016. *Traffic Commissioner PSV notices and proceedings* [online]. Data.Gov.Uk. Available from: https://www.gov.uk/government/collections/traffic-commissioner-notices-and-proceedings [Accessed 21 Nov 2016].

Commissioners, T., 2017. *Traffic Commissioners' Annual Reports* [online]. gov.uk. Available from: https://www.gov.uk/government/collections/traffic-commissioners-annual-reports.

Country, T. and Eu-funded, A., 2015. SAFEWAY2SCHOOL Result In Brief, 1–2.

DCED, 2018. *Sample Size Calculator* [online]. The donor committee for enterprise development. Available from: https://www.enterprise-development.org/measuring-results-the-dced-standard/sample-size-calculator/ [Accessed 21 Jun 2018].

Department for Education, 2014. Home to school travel and transport guidance: Statutory guidance for local authorities, (July), 1–37.

Desrosiers, J., J.A., F., Rousseau, J.-M., Lapalme, G., and Chapleau, L., 1981. AN OVERVIEW OF A SCHOOL BUSING SYSTEM. *SCIENTIFIC MANAGEMENT OF TRANSPORT SYSTEMS EDITED BY NK JAISWAL*.

DfE and National Statistics, 2017. *Schools, Pupils, and Their Characteristics* [online]. gov.uk. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/650547/SFR28_2017_Main_Text.pdf.

DfT, 2017a. *Department for Transport (Great Britan) Road Safety Data - Datasets* [online]. Data.Gov.Uk. Available from: https://data.gov.uk/dataset/road-accidents-safety-data [Accessed 23 Mar 2018].

DfT, 2017b. *Transport Statistics Great Britain 2017* [online]. Statistics. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/att achment_data/file/661933/tsgb-2017-report-summaries.pdf.

DfT - Ras50005, 2017. *Department for Transport (Great Britan) : Contributory factors for reported road accidents* [online]. Data.Gov.Uk. Available from: https://www.gov.uk/government/statistical-data-sets/ras50-contributory-factors [Accessed 23 Mar 2018].

Doohan, I. and Saveman, B. I., 2014. Impact on life after a major bus crash - a qualitative study of survivors' experiences. *Scandinavian Journal of Caring Sciences*, 28 (1), 155–163.

Drake, R., 2016. *Schools, pupils and their characteristics* [online]. Data.Gov.Uk. Available from: https://www.gov.uk/government/statistics/schools-pupils-and-their-characteristics-january-2016 [Accessed 17 Nov 2016].

DVLA, 2017a. Driving-Licence-data-june2017. *gov.uk*.

DVLA, 2017b. *Penalty Points* [online]. Department for Transport. Available from: https://www.gov.uk/penalty-points-endorsements/overview [Accessed 27 Jan 2017].

DVSA, 2011. Public Service Vehicle Operator Licensing Guide for Operators.

DVSA, 2013. *National standard for driving buses and coaches* [online]. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/377669/national-standard-for-driving-buses-and-coaches.pdf.

DVSA, 2014a. *Staying legal : PSV driver basics*.

DVSA, 2014b. Guide to maintaining roadworthiness. [online], (2014), 54. Available from: https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/321988/guide-to-maintaining-roadworthiness.pdf.

DVSA, 2014c. *Careless Torque Costs Lives*.

DVSA, 2016a. *Drivers' hours and tachographs rules: buses and coaches (PSV375)* [online]. gov.uk. Available from: https://www.gov.uk/guidance/drivers-hours-passenger-vehicles.

DVSA, 2016b. *Use the Operator Compliance Risk Score (OCRS) system* [online]. gov.uk. Available from: https://www.gov.uk/guidance/use-the-operator-compliance-risk-score-ocrs-system [Accessed 30 Jul 2017].

DVSA, 2016c. *The safe operator's guide* [online]. Available from: https://www.infrastructure-ni.gov.uk/sites/default/files/publications/doe/driver-vehicle-agency-safe-operators-guide-march-2016.pdf.

DVSA, 2016d. *Use the Operator Compliance Risk Score (OCRS) system*. gov.uk.

DVSA, 2018. *Categorisation of vehicle defects* [online]. gov.uk. Available from: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/707667/categorisation-of-vehicle-defects.pdf.

Easterby-Smith, M., Thorpe, R., and Jackson, P. R., 2012. *Management research*. Sage.

Edmonston, C. J. and Sheehan, M. C., 2001. ' Safe school travel is no accident !' - Applying the Haddon Matrix to school transport safety.

Eltahan, S., Kristl, J., and Javed, A., 2018. Circular business model–Access based car service: A Quantitative Study from customers´ perspective.

Espinoza, J., 2015. Coach driver killed as bus carrying British schoolchildren crashes in Belgium. *telegraph.co.uk* [online], 28 June 2015. Available from: http://www.telegraph.co.uk/news/worldnews/europe/belgium/11704108/One-killed-as-bus-carrying-British-schoolchildren-crashes-in-Belgium.html.

Euchi, J. and Mraihi, R., 2012. The urban bus routing problem in the Tunisian case by the hybrid artificial ant colony algorithm. *Swarm and Evolutionary Computation* [online], 2, 15–24. Available from: http://dx.doi.org/10.1016/j.swevo.2011.10.002.

Falkmer, T., Horlin, C., Dahlman, J., Dukic, T., Barnett, T., and Anund, A., 2014. Usability of the SAFEWAY2SCHOOL system in children with cognitive disabilities. *European Transport Research Review*, 6 (2), 127–137.

Faraj, M. F., Sarubbi, M., Silva, C. M., Porto, M. F., Tadeu, N., and Nunes, R., 2014. A Real Geographical Application for the School Bus Routing Problem. *17th International Conference on Intelligent Transportation Systems (ITSC), Qingdao, China.*, 2762–2767.

Faulkner, G. and Hinckson, E., 2018. *14 - School Travel Plans* [online]. Children's Active Transportation. Elsevier Inc. Available from: https://doi.org/10.1016/B978-0-12-811931-0.00014-4.

Fox, A. and Bumett, R., 2016. British teen crawled through bus wreckage with a broken back to escape Spain crash that killed 13 students. *mirror.co.uk* [online], 21 March 2016. Available from: http://www.mirror.co.uk/news/uk-news/british-teen-crawled-through-bus-7599983.

Gill, P., Stewart, K., Treasure, E., and Chadwick, B., 2008. Methods of data collection in qualitative research: interviews and focus groups. *British dental journal*, 204 (6), 291.

Harrison, F., Burgoine, T., Corder, K., van Sluijs, E. M. F., and Jones, A., 2014. How well do modelled routes to school record the environments children are exposed to?: A cross-sectional comparison of GIS-modelled and GPS-measured routes to school. *International journal of health geographics* [online], 13 (1), 5. Available from: http://www.pubmedcentral.nih.gov/articlerender.fcgi?artid=3942764&tool=pmcentrez&rendertype=abstract.

Hellevik, O., 1988. *Introduction to causal analysis: Exploring survey data by cross-tabulation*. Oxford University Press.

Hemalatha, R., Divakar, S., Logesh, D., and Kumar, M., 2017. Rfid based school children security system. *International Research Journal of Engineering and Technology(IRJET)* [online], 4 (3), 3–5. Available from: https://irjet.net/archives/V4/i3/IRJET-V4I3474.pdf.

Hesse-Biber, S., 2010. Qualitative approaches to mixed methods practice. *Qualitative Inquiry*, 16 (6), 455–468.

Hine, J. and Preston, J., 2017. *Integrated Futures and Transport Choices: UK Transport Policy Beyond the 1998 White Paper and Transport Acts: UK Transport Policy Beyond the 1998 White Paper and Transport Acts*. Routledge and Kegan Paul (Originally published in 1937).

Huang, Z., Gao, Z., Lu, H., Zhang, J., Feng, Z., and Xia, H., 2014. An Mobile Safety

Monitoring System for Children. *2014 10th International Conference on Mobile Ad-hoc and Sensor Networks* [online], 323–328. Available from: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=7051788.

Hutchins, R. and Kinnear, N., 2012. PUBLISHED PROJECT REPORT PPR648 Review of " A Guide to Improving School Transport Safety " R Hutchins and N Kinnear.

Ipingbemi, O. and Aiworo, A. B., 2013a. Journey to school, safety and security of school children in Benin City, Nigeria. *Transportation Research Part F: Traffic Psychology and Behaviour* [online], 19, 77–84. Available from: http://dx.doi.org/10.1016/j.trf.2013.03.004.

Ipingbemi, O. and Aiworo, A. B., 2013b. Journey to school, safety and security of school children in Benin City, Nigeria. *Transportation Research Part F: Traffic Psychology and Behaviour*, 19, 77–84.

Ivankova, N. V, Creswell, J. W., and Stick, S. L., 2006. Using Mixed-Methods Sequential Explanatory Design: From Theory to Practice. *Field Methods* [online], 18 (1), 3–20. Available from: https://doi.org/10.1177/1525822X05282260.

Jamie, G., 2018. *Coach Hire Quote Engine* [online]. www.coachhire4u.com. Available from: http://www.coachhire4u.com/about-us/ [Accessed 29 Sep 2018].

Kalogirou, K., Chalkia, E., Bekiaris, E., and Diederichs, F., 2012. An Application for the Information of Children According their School Transportation. *Procedia - Social and Behavioral Sciences* [online], 48, 363–372. Available from: http://dx.doi.org/10.1016/j.sbspro.2012.06.1016.

Kim, B.-I., Kim, S., and Park, J., 2012. A school bus scheduling problem. *European Journal of Operational Research* [online], 218 (2), 577–585. Available from: http://dx.doi.org/10.1016/j.ejor.2011.11.035.

Kinable, J., Spieksma, F. C. R., and Vanden Berghe, G., 2014. School bus routing-a column generation approach. *International Transactions in Operational Research* [online], 21 (3), 453–478. Available from: http://www.scopus.com/inward/record.url?eid=2-s2.0-84897459986&partnerID=tZOtx3y1.

Kinnear, N. and Smith, L., 2010. *A Guide to Improving School Transport Safety: Casualty risk, responsibilities and legal requirements, and ten ways to reduce risk on the school journey*.

Kotoula, K., Botzoris, G., Morfoulaki, M., and Aifandopoulou, G., 2017a. The existing school transportation framework in Greece - Barriers and problems comparing to other European countries. *Transportation Research Procedia* [online], 24, 385–392. Available from: http://dx.doi.org/10.1016/j.trpro.2017.05.096.

Kotoula, K., Botzoris, G., Morfoulaki, M., and Aifandopoulou, G., 2017b. The existing school transportation framework in Greece - Barriers and problems comparing to other European countries. *Transportation Research Procedia*, 24, 385–392.

Lew, A. F. R., Chew, B. C., and Hamid, S. R., 2018. Green Logistics Implementation Factors: A Study on a Global Logistics Provider. *Journal of Advanced Manufacturing Technology (JAMT)*, 12 (1 (1)), 115–128.

Mammen, G., Stone, M. R., Buliung, R., and Faulkner, G., 2015. “Putting school travel on the map”: Facilitators and barriers to implementing school travel planning in Canada. *Journal of Transport & Health* [online], 2 (3), 318–326. Available from: http://linkinghub.elsevier.com/retrieve/pii/S2214140515002200.

ManchesterCouncil, n.d. *STATS19 road accident injury statistics - report form* [online]. Available from: https://data.gov.uk/dataset/gm-road-casualty-accidents/resource/126487b5-8f1c-4818-8f56-df2982daad1d.

Martin, C., 2016. *The Quantitative Research Sample Size Calculator* [online]. Flexmr. Available from: https://www.flexmr.net/blog/quantitative-research/2016/2/sample-size-calculator.aspx.

MAST, 2018. *Road Safety Analysis Data* [online]. road safety analysis. Available from: http://www.roadsafetyanalysis.org/portfolio-item/mast-online/ [Accessed 23 Mar 2018].

Miranda, D. M., de Camargo, R. S., Conceição, S. V., Porto, M. F., and Nunes, N. T. R., 2018. A multi-loading school bus routing problem. *Expert Systems with Applications* [online], 101, 228–242. Available from: https://doi.org/10.1016/j.eswa.2018.02.014.

Move, D. G., 2016. Comprehensive Study on Passenger Transport by Coach in Europe, (April).

Mulla, A., 2015. GPS Assisted Standard Positioning Service for Navigation and Tracking : Review & Implementation, 00 (M).

Mulugeta, A., 2017. Determinants of Multimodal Transport Effectivness: the Case of Ethiopian Shipping and Logistics Services Enterprise.

Newton, R. M. and Thomas, W. H., 1969. Design of school bus routes by computer. *Socio-Economic Planning Sciences*, 3 (1), 75–85.

NorthamptonshireCountyCouncil, 2016. *School Transport Policy* [online]. Available from: http://www.northamptonshire.gov.uk/en/councilservices/EducationandLearning/Parents/travel/Pages/HtoS.aspx [Accessed 31 Dec 2016].

O'neal, E., Ramirez, M., Cara, H., Tracy, Y., Stahlhut, M., and Peek-Asa, C., 2014. School Bus Crash Rates on Routine and. *Journal of School Health*, 84 (9), 575–580.

Pacheco, J., Caballero, R., Laguna, M., and Molina, J., 2012. Bi-Objective Bus Routing: An Application to School Buses in Rural Areas. *Transportation Science*, 1655 (Osman 1993), 1–15.

Park, J. and Kim, B. I., 2010. The school bus routing problem: A review. *European Journal of Operational Research* [online], 202 (2), 311–319. Available from: http://dx.doi.org/10.1016/j.ejor.2009.05.017.

Park, J., Tae, H., and Kim, B. I., 2012. A post-improvement procedure for the mixed load school bus routing problem. *European Journal of Operational Research* [online], 217 (1), 204–213. Available from: http://dx.doi.org/10.1016/j.ejor.2011.08.022.

Pérez-Martín, P., Pedrós, G., Martínez-Jiménez, P., and Varo-Martínez, M., 2018. Evaluation of a walking school bus service as an intervention for a modal shift at a primary school in Spain. *Transport Policy*, 64 (January), 1–9.

R, C. K., N, V., Ashiq, S. T., and Reddy, G. B., 2018. BITS (Bus integrated tracking system). *International Journal of advance research, ideas and innovations in technology*, 4 (3), 1005–1009.

Ramachandran, M., Sahandi, R., Prakoonwit, S., and Khan, W., 2016. Intelligent safety transport framework for schools: A review of route planning and tracking systems. *In*: *MATEC Web of Conferences*.

Ramachandran, M., Sahandi, R., Prakoonwit, S., and Khan, W., 2017. Mathematical Model for Safety Score Calculation for Validation of Coach Operators in the UK. *In*: *Intelligent Transport Systems – From research and development to the market uptake*. Springer.

Ramachandran, M., Sahandi, R., Prakoonwit, S., and Khan, W., 2018a. Coach Travel Safety Analysis Matrix (CTSAM). *In*: *International Conference on Electrical, Electronics, Computers, Communication, Mechanical and Computing (EECCMC)*.

Ramachandran, M., Sahandi, R., Prakoonwit, S., and Khan, W., 2018b. An Intelligent Recommendation Model for Coach Operators. *In*: *International Conference on Electrical, Electronics, Computers, Communication, Mechanical and Computing (EECCMC)*.

Ramachandran, M., Sahandi, R., Prakoonwit, S., Khan, W., and Mohd Selamat, S. A., 2017. A Safety Transport Model for Validation of UK Coach Operators for School Journeys. *Intelligent Transport Systems – From research and development to the market uptake*.

RAND-Qatar Policy Institute, 2012. *Qatar's School Transportation System - Supporting Safety, Efficacy, and Service Quality*.

Rich, R. C., Brians, C. L., Manheim, J. B., and Willnat, L., 2018. *Empirical political analysis: Quantitative and qualitative research methods*. Routledge.

Riera-Ledesma, J. and Salazar-González, J. J., 2012. Solving school bus routing using the multiple vehicle traveling purchaser problem: A branch-and-cut approach. *Computers and Operations Research*, 39 (2), 391–404.

Riera-Ledesma, J. and Salazar-González, J. J., 2013. A column generation approach for a school bus routing problem with resource constraints. *Computers and Operations Research*, 40, 566–583.

Van Ristell, J. a., Quddus, M. a., Enoch, M. P., Wang, C., and Hardy, P., 2014. Quantifying the impacts of subsidy policies on home-to-school pupil travel by bus in England. *Transportation* [online], 42 (1), 45–69. Available from: http://link.springer.com/10.1007/s11116-014-9525-6.

Robson, C. and McCartan, K., 2016. *Real world research*. John Wiley & Sons.

Saranya, J. and Selvakumar, J., 2013. Implementation of children tracking system on android mobile terminals. *International Conference on Communication and Signal Processing, ICCSP 2013 - Proceedings*, 961–965.

Saunders, M., Lewis, P., and Thornhill, A., 2008. *Research Methods for Business Students*. Research methods for business students.

Schittekat, P., Kinable, J., Sörensen, K., Sevaux, M., Spieksma, F., and Springael, J., 2013. A metaheuristic for the school bus routing problem with bus stop selection. *European Journal of Operational Research* [online], 229 (2), 518–528. Available from: http://dx.doi.org/10.1016/j.ejor.2013.02.025.

Scottish Government, 2015. Summary Statistics for Schools in Scotland No. 6: 2015 Edition. *gov.uk* [online], (7), 1–47. Available from: http://www.gov.scot/Publications/2015/12/7925.

Shaaban, K., Bekkali, A., Hamida, E. Ben, and Kadri, A., 2013. Smart Tracking System for School Buses Using Passive RFID Technology to Enhance Child Safety. *Journal of Traffic and Logistics Engineering* [online], 1 (2), 191–196. Available from: http://www.jtle.net/index.php?m=content&c=index&a=show&catid=32&id=51.

Silva, C. M., Sarubbi, J. F. M., Silva, D. F., Porto, M. F., and Nunes, N. T. R., 2015. A Mixed Load Solution for the Rural School Bus Routing Problem.

Skok, W. and Baker, S., 2018. Evaluating the impact of Uber on London's taxi service: A critical review of the literature. *Knowledge and Process Management*.

Stark, J., Beyer Bartana, I., Fritz, A., Unbehaun, W., and Hössinger, R., 2018. The influence of external factors on children's travel mode: A comparison of school trips and non-school trips. *Journal of Transport Geography* [online], 68 (December 2016), 55–66. Available from: https://doi.org/10.1016/j.jtrangeo.2018.02.012.

Takalikar, N., Ugadepatil, M., Pethe, S., and Sahu, P. R., 2018. School Bus Safety System. *International Research Journal of Engineering and Technology (IRJET)*, 5 (4), 4160–4162.

The Scottish Government, 2009. *Scotland's Road Safety Framework to 2020*.

Villa-González, E., Barranco-Ruiz, Y., Evenson, K. R., and Chillón, P., 2018. Systematic review of interventions for promoting active school transport.

Preventive Medicine [online], 111 (2017), 115–134. Available from: https://doi.org/10.1016/j.ypmed.2018.02.010.

VOSA, 2011. *Rules on Drivers ' Hours and Tachographs: Passenger-carrying vehicles in GB and Europe*.

VOSA - DVSA, 2014. *Vehicle and Operator Services Agency was replaced by Driver and Vehicle Standards Agency in April 2014* [online]. gov.uk. Available from: https://www.gov.uk/government/organisations/vehicle-and-operator-services-agency.

Welsh Government, 2017. School Census Results, 2017. *gov.uk* [online], (July). Available from: http://gov.wales/docs/statistics/2017/170726-school-census-results-2017-en.pdf.

Westman, J., Olsson, L. E., Gärling, T., and Friman, M., 2017. Children's travel to school: satisfaction, current mood, and cognitive performance. *Transportation* [online], 44 (6), 1365–1382. Available from: https://doi.org/10.1007/s11116-016-9705-7.

William, H., 1972. A logical framework for categorizng highway safety phenomena and activity. *Journal of Trauma*.

Woodcock, R. W., Mather, N., and Schrank, F. A., 2004. *Woodcock-Johnson III diagnostic reading battery*. Riverside Pub.

Yasmin, S., Anowar, S., and Tay, R., 2013. Factors Contributing to School Bus Crashes, 52 (3), 63–78.

Yasmin, S., Mechanics, A., and Anowar, S., 2014. Effects of Drivers ' Action on the

Severity of School Bus Collision Effects of Drivers ' Action on the Severity of School Bus Collision, (July 2013), 1–16.

Zambada, J., Quintero, R., Isijara, R., Galeana, R., and Santillan, L., 2015. An IoT based scholar bus monitoring system. *2015 IEEE First International Smart Cities Conference (ISC2)*.

Appendices

Appendix 1 – Coach Travel Safety Analysis Matrix (CTSAM)

Journey sequence	Human/Host	Agent/Vehicle	Physical Environment
Pre-Journey	**Accident Awareness:** 1. Are you aware of any school transport related crashes in your school or any other schools? (T, S,P,C, D) 2. What might be the possible cause of school transport accidents? (T, S, P, C, D) **Safety Measures:** 1. What are all the safety measures taken in **your council** for the school transport (bus stops, route planning, campaigns)? (T) 2. Are there any safety protocols followed while waiting at the bus stop, boarding into the coach, travelling in the coach and getting down from the coach? (T, S,C, D) 3. How strictly are the guidelines are followed in school transport? (T, S, P, C, D) **Driver Check:** 1. Who will verify the drivers CRB, license and driving hours? (T, S, C, D) 2. Do you prove any special training for the school coach drivers? (C) 3. Do you have any assessment of driver physical and mental health? Would you tell more about it? (C) **Children Safety:** 1. Are children provided with any safety briefing before using the school transport for the first time? (C)	**Vehicle Safety:** 1. How do you know that the coaches are in good condition? Do you have any daily checks? (T, S, C, D) 2. Who usually checks MOT, Insurance, safety checks and general condition? (T, S, P, C, D) 3. Do the schools check any of the above? OR does the council verify any of the above? (T, S, P, C, D) 4. How do you know that the companies are adhering to these guidelines? (T, S, P, C, D) 5. Are the selected vehicles always safe? Could you a say a few words on how safe they are? (T, S, P, C, D) 6. Are there any restrictions on what you supply? (e.g.) age of the vehicle? (C) **Safety Measures:** 1. Which safety measures (technical, educational, bus stops, road design) were taken on **the coach** concerning school transport? (C, D) **Children Safety:** 1. How safe are the children while getting onto the coach? (T,S,P,C,D)	**Coach Operating Environment and Procedures** 1. What kind of road constraints has been considered for school transport? E.g. [40km/h] zones. (C, D) 2. How important is it to have a proper Student, Driver education? (C, D) 3. Have you had a special training as a coach driver for school transport? If yes, please describe the training. (D) **Route Safety:** 1. What safety measures (technical, educational, bus stops, toad design) were taken **on your route** concerning school transport? (T, D) 2. Who is in charge of selecting the coach routes? (T, S, P, C, D) 3. Are the selected routes always safe? Could you say a few words on how safe they are? (T, S, P, C, D) 4. Are you using any software for route planning or is it done manually? (T, S, C) 5. Do you use any safety framework for school transport? (T, S, C) 6. What are all the constraints that have been considered in route planning? (T, S, C) 7. Have any safety-related constraints been considered in planning the routes? (T, C) 8. Are parents involved in route planning? (T, C) **Children Safety:** 1. How safe are the children are at the bus stops? (T, S, P, C, D)

Journey	**Children Safety:** 1. How safe are the children while travelling on the coach? (T, S,P,C, D) 2. How do you make sure that children are wearing the seatbelt on the coach? (C, D) 3. How do you react when a student is coming out of the seat or disturbing you while driving or fighting with each other? Do you ever face such problems in your driving experience? (D) **Stakeholder Communication:** 1. Do you communicate or would you like to communicate for safety reasons with the following actors during travel? (D) a. School transport department? Why? b. Parents e.g. if a child does not appear or has (health) problems? c. Authorities e.g. you detect a “nearly accident” and want to report it? (D) 2. What kind of technology do you use to communicate with parents and school transport department? (D)	**Stakeholder Communication:** 1. How important it is to let the parents know about the school coach location (Phone call or GPS)? (D) **Problems During Travel:** 1. What unsafe/risky situations have you experienced while driving the coach? Please describe the situation. What increases the safety in coaches for school transport? (D) 2. What unsafe/risky situation have you experienced driving on a particular route? Are all the short routes safe? (D) 3. What are all the problems that arise in the short/long routes? (D) 4. What defines a safe route in your opinion? (D)	**Problems:** 1. How do you reroute during travel if a normal route is blocked due to road work or accident? (D) 2. How do you mitigate the weather problems arise during the journey? (D)
Post Journey	**Children Safety:** 1. How safe are the children while getting down from the coach? (T, S, P, C, D) **Problems:** 2. What kind of experiences (good/bad) from coach/bus stop is usually reported by the coach driver? (T, S, P, C) 3. What kind of experiences (good/bad) from the coach/bus stop is usually reported by the pupils (students)? (T, S, P, C) 4. What kind of experiences (good/bad) from coach/bus stop is usually reported by parents? (T, S, C) 5. What kind of risks are usually faced by the drivers/students during the travel that are reported to the management? (T, S, P, C) 6. What kind of experiences (good/bad) are usually reported by the school? (C, P) **Preventions, Suggestions & Future Enhancements:** 1. What are all the safety aspects that must be on a route for school	**Emergency Procedures:** 1. What kind of safety measures are in place if a school vehicle meets with an accident? (T,S,C,D)	

	transport to prevent accidents? (T, C, D) 2. What is your suggestion to enhance the safety of school travel? (T, S, P, C, D) 3. What are the criteria that can be considered during the safe school route planning? (T, S, P,C, D) 4. What kind of system/technology do you expect that will improve the safety in school travel? (T, S, P, C, D) 5. Is there anything important concerning school transport, that wasn't spoken about? (T, S,P,C, D)		

Legends:

T – Town Council – Local Authorities – Road Safety Analysts

S – School head teachers/ School transport in charge

P – Parents

C – Coach providers

D – Coach Drivers

Appendix 2 – Questions for semi-structured interviews taken from CTSAM

Focus group:

I) School transport officers
II) Bus drivers
III) National transport officers (town council)
IV) Coach providers
V) Parents

School transport officers – Transport Planners

Profile

(Personal data like name, organization, role and experience)

Basic: (Background)

1. Is transport in your school run by school management or privately hired?
2. What is the rough percentage of children who use the school bus?
3. Who has the main responsibility for organizing school transport in your school?
4. Who is in charge of selecting the bus routes?
5. Are you using any software for route planning or it is done manually?
6. Are you using any safety framework for school transport?
7. What are all the conditions that are considered for route planning? Eg. Bus stops in a route
8. Any safety-related constraints considered for planning the routes?

Accident Statistics:

1. Are you aware of any school transport related crashes in your school or any other schools?
2. What might be the possible cause for school transport accidents?
3. Are the selected routes always safe? Could you say a few words how safe they are?

Problems:

1. What kind of experiences (good/bad) from bus/bus stop usually reported by the bus driver?
2. What kind of experiences (good/bad) from bus/bus stop usually reported by the pupils (students)?
3. What kind of experiences (good/bad) from bus/bus stop usually reported by parents?
4. What kind of risks usually faced by the drivers/students during the travel that are reported to the management?

Children Safety:

1. How safe are the children are at the bus stops?
2. How safe are the children while getting into the bus?
3. How safe are the children while travelling on the bus?
4. How safe are the children while getting down from the bus?
5. Is there any safety protocols followed while waiting in the bus stop, boarding into the bus, travelling on the bus and getting down from the bus?

Vehicle Safety:

1. How do you know that the buses are in good condition? Do you have any daily checks?
2. Who usually checks the Bus condition like MOT and Insurance?
3. Who will verify the drivers CRB, license and driving hours?

Future enhancements/Suggestions:

1. What will be your suggestion to enhance the safety of school travel?
2. What are all the criteria that can be considered during the safe school route planning?
3. What kind of system/technology that you expect that will improve the safety in school travel?
4. Is there anything important concerning school transport, that wasn't talked about?

Bus Drivers

Profile

(Personal data like name, age, type of bus, type of route: one school or more and experience)

Experiences: (Problems)

1. Which unsafe/risky situations have you experienced while driving the bus? Please describe the situation. What increases the safety in buses for school transport?
2. Which unsafe/risky situation have you experienced driving on a particular route? Are all the short routes being safe routes?
3. What are all the problems that arise in the short/long routes?
4. What defines a safe route form your perspective?

Children Safety:

1. How safe are the children are at the bus stops?
2. How safe are the children while getting into the bus?

3. How safe are the children while travelling on the bus?
4. How safe are the children while getting down from the bus?
5. Are there any safety protocols followed while waiting in the bus stop, boarding into the bus, travelling on the bus and getting down from the bus?
6. How do you make sure that children are wearing the seatbelts in the bus?
7. How do you react when a student is coming out of the seat or disturbing you while driving or fighting with each other? Do you ever face such problems in your driving experience?

Vehicle Safety:

1. How do you know that the buses are in good condition? Do you have any daily checks?
2. Who usually checks the Bus condition like MOT and Insurance?
3. Who will verify your CRB, license and driving hours?

Safety Measures:

1. Which safety measures (technical, educational, bus stops, road design,..) were taken **on your route** concerning school transport?
2. Which safety measures (technical, educational, bus stops, road design,..) were taken **on your bus** concerning school transport?
3. Have you had a special training as a bus driver for school transport? If yes please describe the training.

Stakeholder Communication:

1. Do you communicate or would like to communicate for safety reasons with the following actors?
    a. School transport department? Why?
    b. Parents e.g. if a child does not appear or has (health) problems?
    c. Authorities e.g. you detect a “nearly accident” and want to report it?
2. How you reroute during travel if a normal route is blocked dude to road work or accident?
3. How important it is to let know the parents about the school bus location (GPS)?
4. What kind of technology are you using to communicate with parents and school transport department?

Prevention – Future enhancements:

1. What are all the safety aspects that have to be on a route for school transport to prevent accidents?
2. What will be your suggestion to enhance the safety of school travel?
3. Is there anything important concerning school transport, that wasn’t talked about?

Transport Officers – Local authorities (Town Council)

Basic: (Background)

1. How is school transport (ride to and from the school) by bus organized in your council?
2. Whether the schools have their own busses or rent from coach operators?
3. What is the rough percentage of people using school transport in your council?
4. What percentage of schools has their own school buses?
5. Who organizes school transport?
6. Who is responsible for route planning of the school transport?
7. What are all the safety aspects (constraints) considered?
8. Are the parents involved in route planning? Or decision making i.e school governor's
9. Is there any documentation of these responsibilities?

Accident Statistics:

1. Are you aware of any school transport related crashes in your council school or any other schools?
2. What might be the possible cause for school transport accidents?
3. Are the selected routes always safe?

Experiences: (Problems)

1. What are your experiences (problems,…) concerning school transport in your council?
2. Please describe the cooperation with schools, bus driver, bus operators, local and national policy makers and parents.

Safety measures

1. What are all the safety measures taken in your council for the school transport (bus stops, route planning, campaigns,..)?

Children Safety:

1. How safe are the children at the bus stops?
2. How safe are the children while getting into the bus?
3. How safe are the children while travelling on the bus?
4. How safe are the children while getting down from the bus?
5. Are there any safety protocols followed while waiting in the bus stop, boarding into the bus, travelling on the bus and getting down from the bus?
6. Would you like a set of safety protocols to follow?

Vehicle Safety:

1. How do you know that the buses are in good condition? Do you have any frequent updates or access to vehicle conditions?
2. Who usually checks the Bus condition like MOT and Insurance?
3. Who will verify your CRB, license and driving hours?

Future enhancements/Suggestions:

1. What will be your suggestion to enhance the safety of school travel?
2. What are the criteria that can be considered during the safe school route planning?
3. What kind of system/technology that you expect that will improve the safety in school travel?
4. Is there anything important concerning school transport, that wasn't talked about?

Coach Providers

Profile

(Personal data like name, organization, role and experience)

Basic: (Background)

1. For how many schools do you provide coach services?
2. What is the rough percentage of children who use the school bus?
3. Who has the main responsibility for organizing school transport from the schools you provide?
4. Who is in charge of selecting the bus routes? Schools councils etc?
5. Are you using any software for route planning or it is done manually?
6. Are you using any safety framework for school transport?
7. What are all the constraints that considered for route planning?
8. Any safety-related constraints considered for planning the routes?
9. Is there any restriction on what you supply? (eg.) age of the vehicle?

Accident Statistics:

1. Are you aware of any school transport related crashes in your school or any other schools?
2. What might be the possible cause for school transport accidents?
3. Are the selected routes always safe?

Problems:

1. What kind of experiences (good/bad) from bus/bus stop usually reported by the bus driver?
2. What kind of experiences (good/bad) from bus/bus stop usually reported by the pupils (students)?

3. What kind of experiences (good/bad) from bus/bus stop usually reported by parents?
4. What kind of risks usually faced by the drivers/students during the travel that are reported to the management?
5. What kind of experiences (good/bad) usually reported by the school?

Children Safety:

1. How safe are the children are at the bus stops?
2. How safe are the children while getting into the bus?
3. How safe are the children while travelling on the bus?
4. How safe are the children while getting down from the bus?
5. Are there any safety protocols followed while waiting in the bus stop, boarding into the bus, travelling on the bus and getting down from the bus? And who supply them?

Vehicle Safety:

1. How do you know that the buses are in good condition? Do you have any daily checks?
2. Who usually checks the MOT, Insurance, safety checks & general condition?
3. Who will verify the drivers CRB, license and driving hours?
4. Are you providing any special training for the school bus drivers?
5. Do you have any assessment for driver physical and mental health? Would you tell more about it?
6. Does the school check any of the above?

Future enhancements/Suggestions:

1. What will be your suggestion to enhance the safety of school travel?
2. What are all the criteria that can be considered during the safe school route planning?
3. What kind of system/technology that you expect that will improve the safety in school travel?
4. Is there anything important concerning school transport, that wasn’t talked about?

Parents

Profile

(Personal data like name, organization, role and experience)

At the bus stop:

Basic: (Background)

1. How many children of yours currently using school transport? For how many years?

Accident Statistics:

1. Are you aware of any school transport related crashes in your child school or any other schools?
2. What might be the possible cause for school transport accidents?
3. Are the selected routes always safe? Could you say a few words how safe they are?

Problems:

1. What kind of experiences (good/bad) from bus/bus stop usually reported by the bus driver?
2. What kind of experiences (good/bad) from bus/bus stop usually reported by the pupils (students)?
3. What kind of risks usually faced by the drivers/students during the travel that are reported to the management?

Children Safety:

1. How safe are the children are at the bus stops?
2. How safe are the children while getting into the bus?
3. How safe are the children while travelling on the bus?
4. How safe are the children while getting down from the bus?

Vehicle Safety:

1. How do you know that the buses are in good condition? Do you have any daily checks?
2. Would you like to know about the MOT and Insurance of the vehicle that your child is travelling?
3. How do you know driver's DBS, license and driving hours?

Future enhancements/Suggestions:

1. What will be your suggestion to enhance the safety of school travel?
2. What are all the criteria that can be considered during the safe school route planning?
3. What kind of system/technology that you expect that will improve the safety in school travel?
4. Is there anything important concerning school transport, that wasn't talked about?

Appendix 3 – Quantitative Survey Questions

Target audience:

1. Parents (Social Sector)

2. Headmasters (Educational Sector)

3. Coach operators (Transport Sector)

4. Coach drivers (Transport Sector)

5. Transport officers & Road safety analysts (Government Sector)

Sampling Size: Based on the number of parents, Headmasters and coach operators in each region of the UK, the sample size will be calculated using the online tools available [2].

Questions type: Descriptive

What are we trying to identify through this quantitative survey?

Based on our survey, we have found a major knowledge gap between the stakeholders in the coach-based school transport. When the parents asked, how they ensure that their children are travelling safely on the coaches? They said they trust the school. When schools were asked, how they ensure that their students are travelling safely in coaches? They said they trust the coach operator. But based on the traffic commissioner's reports, it is hard to assume that all the operators are always complaint with the government regulations and safe for the travel.

The survey was carried out in the area of Luton Borough Council To further explore the survey.

Questions for Parents:

1. How do you ensure that your children are travelling safe on coach arranged by schools with respect to the safety compliance procedures of the coach operator, vehicle and the driver?
    a. I trust the school and believe that they will follow all the safety procedures to ensure the safety of children travelling in coaches.
    b. I trust the school but I also get involved with the coach booking process to make sure they book the safe coach operator.
    c. I am worried about the safety of my child travelling in a coach. So, I drive my child to the spot and drive back home.
    d. Other (Please Specify)

If the answer is b, please proceed to questions 2 to 4,

2. How do you select your coach operator for the journey?
    a. We use experienced operators that we have been using for a long time and we never had any issues.
    b. We ask our council to recommend us the operators for school trips.
    c. We conduct an internet search to find operators with good reviews and low prices.
    d. Other (Please Specify)
3. How do you ensure that the coach operator is compliant with the regulations? (e.g. do you check operator's OCRS scores and driver license points)?
    a. No, we trust the operator that they are compliant with all the government regulations.
    b. Yes, we check the operators OCRS scores and driver(s) license points.
    c. Other (Please Specify)
4. How do you ensure that the details provided by the coach operator are correct?
    a. We trust the operator and accept the information that they provide.
    b. We cross check with the DVLA before booking a coach.
    c. Other (Please Specify)
5. From your point of view, what are the causes of coach accidents when transporting children?
    a. Vehicle error (like a vehicle out of control due to poor maintenance etc.)
    b. Driver errors (like fatigue due to irregular driving hours etc.)
    c. Inexperienced driver
    d. Drivers got disturbed by pupils in the bus
    e. Other vehicle behaviour around the bus (External factors)
    f. Other (Please Specify)
6. Based on a research conducted in the area of Luton Borough Council, we have identified the following requirements by the parents regarding coach-based school trips. Please answer the following questions by putting a ring around the answer;
    a. Do you think it would be useful to have vehicle tracing (GPS tracking of coaches in the form of a mobile app)? – Yes/No
    b. Do you think it would be appropriate to have bus escorts to control children from disturbing the driver while the coach is moving? – Yes/No
    c. Do you think schools should check the status of coaches and their drivers to ensure children will be travelling safely? Yes/No
    d. Do you think CCTV cameras should be used in coaches to record children and also drivers' behaviour? Yes/No

Questions for Headmasters:

1. How do you select your coach operator for a journey?

    a. We use experienced operators that we have been using for a long time and we never had any issue.
    b. We seek a recommendation from our County Council for coach operators for our school's trips.
    c. We conduct an internet search to find operators with good reviews and low prices.
    d. Other (Please Specify)
2. How do you ensure that a coach operator is complaint with the government safety regulations? (e.g. do you check operator's OCRS scores and driver license points)?
    a. No, we trust the operator that they are compliant with all the government regulations.
    b. Yes, we check the operators OCRS scores and driver(s) license points.
    c. Other (Please Specify)
3. How do you ensure that the details provided by the operator are correct?
    a. We trust the operator and accept the information that they provide.
    b. We cross check with the DVLA before booking a coach.
    c. Other (Please Specify)
4. From your point of view, what is the cause for coach accidents during children transport?
    a. Vehicle error (like a vehicle out of control due to poor maintenance etc.)
    b. Driver errors (like fatigue due to irregular driving hours etc.)
    c. Inexperienced driver
    d. Drivers became disturbed by pupils in the bus
    e. Other vehicles/drivers behaviour around the bus (External factors)
    f. Other (Please Specify)
5. Based on a research conducted in the area of Luton Borough Council, we have identified the following requirements by the schools regarding coach-based school transport. Please answer the following questions by putting a ring around the correct answer;
    a. Do you need an efficient mechanism to check vehicle and driver's safety scores before booking a coach? Yes/No
    b. Do you think CCTV cameras would be useful in coaches to record students' and driver's behaviour? Yes/No
    c. Do you think it would be useful to have vehicle tracking (GPS tracking of coaches in the form of a mobile app)? – Yes/No
    d. Do you think it would be appropriate to have bus escorts to control children from disturbing the driver while the coach is moving? – Yes/No

Questions for Coach Operators:

1. In your experience in the coach industry, have you ever been asked by schools to provide information on your OCRS scores, vehicle safety checks and drivers' license points?
    a. No, they never asked.
    b. Yes, but they rarely ask for it.
    c. Yes, they ask for it all the time.
    d. Other (Please Specify)
2. From your point of view, what is normally the cause for coach accidents during transport of school children?
    a. Vehicle error (like a vehicle out of control due to poor maintenance etc.)
    b. Driver errors (like fatigue due to irregular driving hours etc.)
    c. Inexperienced driver
    d. Drivers become disturbed by pupils on the bus
    e. 21 hours continuous driving by 2 drivers
    f. Other vehicle's/drivers' behaviour around the bus (External factors)
    g. Other (Please Specify)
3. Based on a research conducted in the area of Luton Borough Council, we have identified the following requirements of coach operators regarding coach-based school transport. Please answer the following questions by putting a ring around the correct answer:
    a. Do you think it would be appropriate to have bus escorts to control children from disturbing the driver while the coach is moving? – Yes/No
    b. Do you think it would be useful to have vehicle tracking (GPS tracking of coaches in the form of a mobile app)? – Yes/No
    c. Do you need an efficient mechanism to check vehicle and driver's safety scores before booking a coach? Yes/No
    d. Do you think driver – passenger education on coach trips is necessary before the travel? Yes/no
    e. Do you think CCTV cameras would be useful in coaches to record students' and driver's behaviour? Yes/No
    f. Do you need a legislation to stop pupils from distracting driver during the travel? Yes/no

Questions for Coach Drivers:

1. In your experience as a driver in the coach industry, have you ever been asked by schools for information regarding your OCRS scores, vehicle safety checks and drivers' license points?
    a. No, they never asked.
    b. Yes, but they rarely ask for it.
    c. Yes, they ask for it all the time.
    d. Other (Please Specify)

2. From your point of view, what is normally the cause for coach accidents during transport of school children?
    a. Vehicle error (like vehicle out of control due to poor maintenance etc.)
    b. Driver errors (like fatigue due to irregular driving hours etc.)
    c. Inexperienced driver
    d. Drivers become disturbed by pupils on the bus
    e. 21 hours continuous driving by 2 drivers
    f. Another vehicle 's/drivers' behaviour around the bus (External factors)
    g. Other (Please Specify)
3. Based on a research conducted in the area of Luton Borough Council, we have identified the following requirements by coach drivers regarding coach-based school transport. Please answer the following questions by putting a ring around the correct answer:
    a. Do you think it would be appropriate to have bus escorts to control children from disturbing the driver while the coach is moving? – Yes/No
    b. Are you given with proper rooms to stay during the school trips? Yes/no
    c. Do you think it would be useful to have vehicle tracking (GPS tracking of coaches in the form of a mobile app)? – Yes/No
    d. Do you need an efficient mechanism to check vehicle and driver's safety scores before booking a coach? Yes/No
    e. Do you think driver – passenger education on coach trips is necessary before the travel? Yes/no
    f. Do you think CCTV cameras would be useful in coaches to record students' and driver's behaviour? Yes/No
    g. Do you need a legislation to stop pupils from distracting driver during the travel? Yes/No

Transport officers & Road safety analysts Questions

1. Do you think schools check coach operator's OCRS scores, vehicle safety checks and drivers' license points before their children commencing a coach journey?
    a. No, they don't.
    b. Yes, but they rarely check it.
    c. Yes, they check it all the time.
    d. Other (Please Specify)
2. Do you think parents check the coach operator's OCRS scores, vehicle safety checks and drivers' license points before their children commencing a coach journey?
    a. No, they don't.
    b. Yes, but they rarely check it.
    c. Yes, they check it all the time.

d. Other (Please Specify)

3. How do they ensure that you are providing them with the correct information?
    a. They trust us and ask about it verbally but never checked the documents.
    b. They check the documents and trust the operators that they are providing legit information.
    c. They check the documents and cross check with the DVLA before the journey.
    d. They check with the local council.
    e. Other (Please Specify)
4. From your point of view, what is the cause for coach accidents that carrying children?
    a. Vehicle error (like a vehicle out of control due to poor maintenance etc.)
    b. Driver errors (like fatigue due to irregular driving hours etc.)
    c. Inexperienced driver
    d. Drivers become disturbed by pupils on the bus
    e. 21 hours continuous driving by 2 drivers
    f. Other vehicles'/drivers' behaviour around the bus (External factors)
    g. Other (Please Specify)
5. Based on a research conducted in the area of Luton Borough Council, we have identified the following requirements of council transport officers and road safety analysts regarding coach-based school transport. Please answer the following questions by putting a ring around the correct answer:
    a. Do you think it would be appropriate to have bus escorts to control children from disturbing the driver while the coach is moving? – Yes/No
    b. Do you think it would be useful to have vehicle tracking (GPS tracking of coaches in the form of a mobile app)? – Yes/No
    c. Do you need an efficient mechanism to check vehicle and driver's safety scores before booking a coach? Yes/No
    d. Do you think driver – passenger education on coach trips is necessary before the travel? Yes/No
    e. Do you think CCTV cameras would be useful in coaches to record students' and driver's behaviour? Yes/No
    h. Do you need a legislation to stop pupils from distracting driver during the travel? Yes/no
    i. Do you think schools have to check the operator and driver documents before they commence a journey? Yes/no

Appendix 4 – Stakeholder Responses for Framework Evaluation

School Headmaster/Parents: 70 responses in total

Questions for School Headmasters/Parents:

1. Do you think the approach taken by the framework consider suitable and relevant information for validating the safety?
    a. Yes (70 – 100%)
    b. No (0)
    c. Other (0)
2. Do you think all the steps used in the coach journey validator are necessary and valid to qualify an operator/driver?
    a. Yes (70 – 100%)
    b. No (0)
    c. Other (0)
3. Do you think sufficient data is collected in Step 1 to validate the coach operators, vehicles and drivers in?
    a. Yes (70 – 100%)
    b. No (0)
    c. Other (0)
4. Does the approach taken in Step 2 to check the authenticity of the checks carried out for drivers and coaches safety appropriate?
    a. Yes (70 – 100%)
    b. No (0)
    c. Other (0)
5. In Step 3, do you think it is appropriate to allocate lesser consideration to different attributes as some attributes have greater significance than others? (Eg. OCRS attribute will have lesser consideration than the daily walk around check attribute)
    a. Yes (70 – 100%)
    b. No (0)
    c. Other (0)
6. In Step 4, do you think the safety score calculation method is appropriate and provides the relevant safety scores?
    a. Yes (70 – 100%)
    b. No (0)
    c. Other (0)

Prototype Evaluation:

1. In Step 5, do you think the Intelligent system provides relevant and appropriate recommendations to coach operators to improve their safety?
    a. Yes (70 – 100%)
    b. No (0)
    c. Other (0)
2. Do you think the prototype clearly illustrates the capability of the framework?

a. Yes (70 – 100%)
b. No (0)
c. Other (0)

3. From the Screen Shot 2, Which one of the Operator will you select?
   a. Operator 1 (65 – 92.9%)
   b. Operator 2 (5 – 7.1%)
   c. Operator 3 (0)
   d. Operator 4 (0)
   e. Operator 5 (0)
4. Do you think this prototype/framework, will improve the safety of school children transport by coaches/buses?
   a. Yes (70 – 100%)
   b. No (0)
   c. Other (0)
5. Overall, how effective do you think this framework is in validating coach operators for school journeys?
   a. Extremely effective (61 - 87.1%)
   b. Quite effective (7 – 10%)
   c. Moderately effective (2 – 2.9%)
   d. Slightly effective (0)
   e. Not at all effective (0)
6. Would you support your academic institution by using a technology framework for assessing student transport safety? (Question only for school Headmasters/parents)
   a. Yes (70 – 100%)
   b. No (0)
   c. Other (0)

Coach Operators: 29 responses in total

Questions for Coach Operators:

1. Do you think the approach taken by the framework consider suitable and relevant information for validating the safety?
   a. Yes (28 – 96.6%)
   b. No (1 – 3.4%)
   c. Other (0)
2. Do you think all the steps used in the coach journey validator are necessary and valid to qualify an operator/driver?
   a. Yes (27 – 96.4%)
   b. No (1 – 3.6%)
   c. Other (0)
3. Do you think sufficient data is collected in Step 1 to validate the coach operators, vehicles and drivers in?
   a. Yes (28 – 96.6%)
   b. No (1 – 3.4%)
   c. Other (0)

4. Does the approach taken in Step 2 to check the authenticity of the checks carried out for drivers and coaches safety appropriate?
    a. Yes (28 – 96.6%)
    b. No (1 – 3.4%)
    c. Other (0)
5. In Step 3, do you think it is appropriate to allocate lesser consideration to different attributes as some attributes have greater significance than others? (Eg. OCRS attribute will have lesser consideration than the daily walk around check attribute)
    a. Yes (28 – 96.6%)
    b. No (1 – 3.4%)
    c. Other (0)
6. In Step 4, do you think the safety score calculation method is appropriate and provides the relevant safety scores?
    a. Yes (28 – 96.6%)
    b. No (1 – 3.4%)
    c. Other (0)
7. In Step 5, do you think the Intelligent system provides relevant and appropriate recommendations to coach operators to improve their safety?
    a. Yes (28 – 96.6%)
    b. No (1 – 3.4%)
    c. Other (0)
8. Do you think that the safety score calculation is appropriate & provide standards for coach operators vehicles & drivers?
    a. Yes (26 – 89.7%)
    b. No (3 – 10.3%)
    c. Other (0)
9. Are the vehicles checks and drivers checks conducted by the method shown in figure 6 accurately verifies vehicles and drivers checks?
    a. Yes (28 – 96.6%)
    b. No (1 – 3.4%)
    c. Other (0)

Prototype Evaluation:

1. Do you think this system will provide enough recommendations to coach operators to improve their safety level?
    d. Yes (26 – 89.7%)
    e. No (3 – 10.3%)
    f. Other (0)
2. Do you think the prototype clearly illustrates the capability of the framework?
    d. Yes (28 – 96.6%)
    e. No (1 – 3.4%)
    f. Other (0)
3. From the Screen Shot 2, Which one of the Operator will you select?
    f. Operator 1 (26 – 89.7%)
    g. Operator 2 (1 – 3.4%)

h. Operator 3 (0)
i. Operator 4 (0)
j. Operator 5 (2 – 6.9%)

4. Do you think this prototype/framework, will improve safety of school children transport by coaches/buses?
   d. Yes (26 – 89.7%)
   e. No (3 – 10.3%)
   f. Other (0)
5. Overall, how effective do you think this framework is in validating coach operators for school journeys?
   f. Extremely effective (19 – 65.5%)
   g. Quite effective (7 – 24.1%)
   h. Moderately effective (1 – 3.4%)
   i. Slightly effective (1 – 3.4%)
   j. Not at all effective (1 – 3.4%)
6. An operator who complies with safety procedure should not fear this framework. As an operator, would you support this evaluator framework?
   d. Yes (29 – 100%)
   e. No (0)

Council Transport Officers/ Road Safety Analysts: 13 responses in total

Questions for Council Transport Officers/Road Safety Analysts:

1. Do you think the approach taken by the framework consider suitable and relevant information for validating the safety?
   a. Yes (13 – 100%)
   b. No (0)
   c. Other (0)
2. Do you think all the steps used in the coach journey validator are necessary and valid to qualify an operator/driver?
   a. Yes (13 – 100%)
   b. No (0)
   c. Other (0)
3. Do you think sufficient data is collected in Step 1 to validate the coach operators, vehicles and drivers in?
   a. Yes (13 – 100%)
   b. No (0)
   c. Other (0)
4. Does the approach taken in Step 2 to check the authenticity of the checks carried out for drivers and coaches safety appropriate?
   a. Yes (12 – 92.3%)
   b. No (1 – 7.7%)
   c. Other (0)
5. In Step 3, do you think it is appropriate to allocate lesser consideration to different attributes as some attributes have greater significance than others?

(Eg. OCRS attribute will have lesser consideration than the daily walk around check attribute)

   a. Yes (13 – 100%)
   b. No (0)
   c. Other (0)

6. In Step 4, do you think the safety score calculation method is appropriate and provides the relevant safety scores?
   a. Yes (13 – 100%)
   b. No (0)
   c. Other (0)

Prototype Evaluation:

1. In Step 5, do you think the Intelligent system provides relevant and appropriate recommendations to coach operators to improve their safety?
   a. Yes (13 – 100%)
   b. No (0)
   c. Other (0)
2. Do you think the prototype clearly illustrates the capability of the framework?
   a. Yes (13 – 100%)
   b. No (0)
   c. Other (0)
3. From the Screen Shot 2, which one of the Operator will you select?
   a. Operator 1 (13 – 100%)
   b. Operator 2 (0)
   c. Operator 3 (0)
   d. Operator 4 (0)
   e. Operator 5 (0)
4. Do you think this prototype/framework, will improve the safety of school children transport by coaches/buses?
   a. Yes (13 – 100%)
   b. No (0)
   c. Other (0)
5. Overall, how effective do you think this framework is in validating coach operators for school journeys?
   a. Extremely effective (10 – 76.9%)
   b. Quite effective (2 – 15.4%)
   c. Moderately effective (1 – 7.7%)
   d. Slightly effective (0)
   e. Not at all effective (0)

Intelligent Safety Transport Framework for Schools: A Review of Route Planning and Tracking Systems

Manoharan Ramachandran[a], Reza Sahandi, Simant Prakoonwit and Wajid Khan

Creative Technology Department, Faculty of Science and Technology, Bournemouth University, Bournemouth, United Kingdom

Abstract. This work presents a review of recent literature in intelligent school transportation frameworks, particularly focusing on route planning, real time vehicle and children tracking. The focus on route planning and tracking is to identify the hidden practical problems and threats present in school transportation, bearing in mind safety. Different methods and technologies used for route planning and vehicle as well as children tracking are reviewed. A discussion is provided on the current frameworks along with the challenges and future research direction.

1 Introduction

School Transportation System (STS) is safety critical which involves school children (students) who are the most vulnerable users of roads [1]. Recent events and accidents highlighted the need for improving the existing school transportation and bus monitoring systems [52], [53]. Statistics demonstrate that in England alone 85,814 children were wounded near the schools during the period 2007 to 2013, which is equivalent to 1,190 a month [2], [3]. Moreover, during the period 2006 to 2011 there were 557,200 vehicle collisions around schools [2], [3]. As a result, proper safety route planning and monitoring strategies for school vehicles and children are in high demand [4], [5]. Efforts to reduce school transport injuries have begun through constraint-based school bus routing [12] and peer to peer children monitoring [13] while they are on route. Recent innovations [6], [7], [8] in STS, gave birth to Intelligent School Transportation Systems (ISTSs), which addressed some of the issues [9], [10], [11] in STS such as optimal routing of school vehicles, continuous monitoring of school buses and children. An ISTS incorporates the innovation and adoption of recent technologies to create applications for the benefit of school transportation. Major technologies involved in ISTS are school bus route planning systems, school vehicle-children tracking and monitoring systems. School bus route planning systems rely on the history of School Bus Routing Problems (SBRPSs) which have been studied since the first published work by Newton and Thomas in 1969 [14]. There are only limited publications available for reviewing school bus routing problems [15], [16], [17]. Junhyuk and Byung-in Kim [17] describe school bus routing problems for a fleet of school buses as an efficient schedule planning, where children are picked up by each bus from various geographical locations and delivered to their respective schools, while satisfying a set of constraints. The main reasons behind the school bus routing problems were frequent changes in the number of children per stop, rerouting during temporary roadworks and traffic jams. According to Desrosiers et.al [15], there are five steps to reduce school bus routing problems, namely, data preparation, bus stop selection, bus route generation, school bell time adjustment and route scheduling. Parents spend more time on the streets and making phone calls while waiting for school buses due to the unpredictable nature of the traffic, particularly during the winter months. For this very reason, vehicle-children tracking systems were made. School vehicle-children tracking is a process of tracking the school bus and children inside it using tracking devices such as the Global Positioning System (GPS) [38] and Radio Frequency Identification (RFID) systems tags [39], which are commonly used in tracking technologies. The tracked data may be utilized by the school transportation department and shared with parents to let them recognize the location of their children. Most of the published work so far on ISTS have focused on route planning systems and only limited work has been done to address the whole school transport system [18], [19]. In this paper, a review of recent studies in intelligent safety school transportation systems with a focus on route planning and tracking is presented. A fresh perspective and functions for an ISTS framework are provided along with the challenges and further research direction.

2 Intelligent School Transportation Systems

It was indicated earlier that ISTSs attempt to provide safe and secure transportation for school children through design, development and integration using appropriate technologies. However, limited works have been done so far in addressing this for school transportation and child

[a] Corresponding author: mramchandran@bournemouth.ac.uk

safety. A recent Europe funded project conducted in Sweden "SAFEWAYTOSCHOOL" provided a holistic and safety framework for children [1], [11], [18], [19], [38]. This project addresses most of the difficulties faced during school transportation through a door to door approach (between home and school). Figure 1 shows a holistic approach to this project. At first, safest routes are considered for children to reach the bus stop. When a child reaches the bus stop, an alert light is automatically turned on at the bus stop. When the bus reaches the bus stop to pick up the child, a warning sign in the bus is turned on. During the journey towards the school, the children are notified to put the seat belts on. Also, audio-visual information is provided about the destination before reaching the school. Once the bus reaches the school stop, a warning notification light is turned on in the bus and the bus stop is also turned on. Finally, on arrival at the school, a notification message is sent to parents.

Atsushi et al., proposed a safety support system through ad-hoc network formed using mobile phones to increase the safety of children when walking between bus stops and home [44]. Volunteers who maintain safety in the local community assist the children when walking between home and bus stop. Both the volunteers and children are provided with mobile phones which facilitate the Bluetooth function. A safety support mobile application is installed on these mobile phones. Bluetooth poles are placed at even distance intervals between the home and bus stop. When children's and volunteer's mobile phones come into contact with these poles, the mobile application automatically connect them. The volunteer's mobile application obtains information about the exact location of the child and shares it with the parents and caretakers. A warning message is sent to parents and volunteers if any abnormalities like deviating from the normal path are found.

Figure 1. Holistic approach of school transportation [18].

3 Functions of ISTSs

School transportation systems have been evolving in the past decades. ISTSs were developed due to recent advancements in route planning systems [6], [12], [23], [29]- [33], [35]-[37], school vehicle-student tracking and monitoring systems [8], [18], [38]-[43]. Figure 2 shows the functions of a typical ISTS. Each ISTS function applies its own methods to find the best solutions [6], [7], [8], [12], [17], [21] for the challenges in each function. For instance, GPS [39] and RFID [18] tags are used for vehicle and student tracking. However, providing an accurate and a non-intrusive service at all time is challenging [7].

3.1 Route Planning Systems

In schools, manual route planning is an intensive task and it consumes a considerable amount of time for selecting appropriate safety routes, as well as the number of busses required for a route. Typically, school transportation departments perform manual route planning at the beginning of each term due to the changes in the number of students using the service. To make this process more efficient, automated route planning systems are used. To avoid school bus routing problems, automated route planning systems utilize the following five steps sequentially: preparation of data, selection of bus stops, generation of school bus routes, adjustment of school bell time and scheduling of school bus routes [15].

3.1.1 Data Preparation (DP):

Data for the next four sub problems (Bus Stop Selection (BSS), Bus Route Generation (BRG), School Bell Time Adjustment (SBTA) and Route Scheduling (RS) of school bus routing problem are created through data preparation. In this step, a dataset containing a single road network with student residence coordinates, the school constraints (start-end time of schools, maximum ride time, etc.), number of vehicles with seating plan and an Origin-Destination (OD) matrix are created. In an OD matrix, the shortest distance between the school location, student locations and the bus origin location are stored. Various shortest path algorithms and a geographic information system (GIS) are applied to calculate the OD matrix [17]. Performances of the shortest path algorithms are compared by Kim and Jeong and an approximation approach for the OD matrix generation is developed [20]. Thus, the dataset (students, schools, vehicles and OD matrix) created in the data preparation is used to prevent school bus routing problems.

3.1.2 Bus Stop Selection (BSS):

It is the process of selecting a number of school bus stops and assigning students to them. Bus stop selection can be done through heuristic approaches [29], [36], [37] or by exact methods based on mathematical programming [12], [21], [22], [23], [37]. The heuristic approach follows either the Location-Allocation-Routing (LAR) [15], [24], [25], [26] or the Allocation-Routing-Location (ARL) [27], [28], [29] strategies. In LAR strategy, a set of bus stops for a school are selected first and the students are

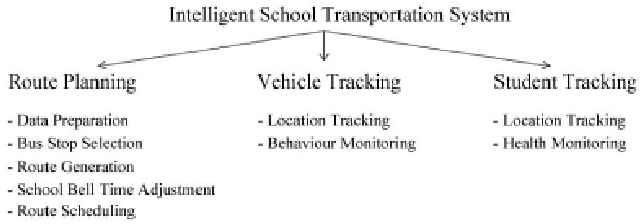


Figure 2. Functions of a typical Intelligent School Transportation System.

allocated to these bus stops based on the distance between the bus stop and their home. Once the children are assigned to these bus stops, the routes are generated. LAR strategy tends to create more routes since bus stop selection and children assignments are done before the route generation. ARL strategy overcomes the drawback of LAR by performing it in the opposite order. At first, children are grouped into clusters with respect to vehicle capacity constraints. Subsequently, bus stops are selected and routes between each cluster are generated. Finally, the clusters are assigned to the bus stop by satisfying constraints such as maximum walking distance between home and bus stop, maximum number of children for a bus stop and minimum distance between each bus stop [17].

3.1.3 Bus Route Generation (BRG):

School bus routes are generated by analysing the data gathered from the previous two processes. The route generation algorithms classified into either "route-cluster" or "cluster-route" approaches [24]. In the "route-cluster" approach, all the stops in a large route are built using the traveling salesman algorithm from which small routes are partitioned based on the constraints [14], [24]. In the "cluster-route" approach, students are grouped into clusters and each cluster is served as a route satisfying the constraints [25], [27], [28]. The constraints that are categorized to minimise school bus routing problem are represented in Table 1. They are, Vehicle Capacity (VC) – number of children allowed for a vehicle, maximum Ride Time (RT) – travel time of each child, school Time Window (TW) – arrival time of vehicle at school, maximum Walking Distance (WD) – distance between student home and bus stop, minimum number of Students for a Route (SR), Passenger Demand (PD) – route request by student during travel, maximum Bus stops Visited (BV), maximum Waiting Time (WT) – allowed waiting time for student at the bus stop and Terrain Type(TT) – type of road selected.

3.1.4 School Bell Time Adjustment (SBTA):

It has performed for schools where the start and end times are not considered as constraints but as decision variables. This is to identify the optimal start and end time to reduce the number of buses used [17].

3.1.5 Route Scheduling (RS):

The start and end times for each route are scheduled through route scheduling using a series of routes that can be visited successfully by the same bus. SBTA and RS are implemented when buses transport students from more than one school.

Minimisation of school bus routing problems is performed based on the nature of the underlying problem characteristics as follows; the number of schools: single (vehicle serves only one school) [35] or multiple (vehicle serves more than one school) [37]; fleet type: homogeneous (vehicles seating capacity remains the same) [23] or heterogeneous (vehicles seating capacity varies) [37]; service type: rural [31] or urban [30]; [17]. Table I also represents a comparison of methods applied by various researchers since 2010 for reducing school bus routing problems. For the work done before 2010, Park and Kim in [17] provide a comprehensive review of school bus routing problem.

3.2 School Vehicle Tracking and Monitoring Systems

School vehicle tracking is similar to common vehicle tracking which involves the use of GPS devices to track the vehicle. A GPS device in the school vehicle automatically provides updates of its location coordinates to a cloud server, which process and plots these coordinates on a virtual map. This map can be accessed by the stakeholders (transport department and parents) for information about the location of the school vehicle. School vehicle tracking systems can be utilized for two purposes: location tracking and vehicle behaviour monitoring

3.2.1 Vehicle Location Tracking (VLT):

The most commonly applied technology for position tracking systems is GPS. Grounded along the tracking nature, location tracking can be classified as real-time tracking [39] and lag-time tracking [38]. In real-time tracking, the location sensor in the vehicle (GPS) frequently updates a server in the real-time [39], [40]. In lag-time tracking, an active RFID unit in the vehicle communicates with the bus stop when it reaches near it and through that the vehicle is tracked [38].

[a] Corresponding author: mramchandran@bournemouth.ac.uk

Table 1. Representation of recent works in school bus routing problem (2010-2016)

Study	Considered school bus routing problem sub Problems	Constraints	Method	Goal
Jalel Euchi et al., 2012 [30]	BSS,BRG,RS	VC,RT,PD	Artificial ant colony with variable neighborhood local search algorithm	Minimizing the total number of buses required
Riera et al., 2012 [23]	BSS,RG	VC,WD	Branch and cut approach based Exact algorithm	Number of routes and route length minimization
Pacheco et al., 2012 [31]	RG,RS	RT	Multi-objective adaptive memory programming	Minimizing the duration of the longest routes and total distance traveled
Byung In et al., 2012 [32]	RS	TW	Branch and bound approach based on assignment problem	Optimization of bus schedules to serve all the given trips within the given TW
Junhyuk et al., 2012[33]	RG,RS	VC,RT,TW	Mixed load improvement algorithm	Minimizing the total number of buses required
Patrick et al., 2013 [29]	BSS,RG	VC,TW,SR,WD	GRASP+VND metaheuristic approach	To integrate BSS and RG through meta-heuristic approach with simplified implementation
Riera et al., 2013 [12]	BSS,RG	VC,RT,SR,BV,WD	Set partitioning formulation based branch and price algorithm	Minimizing the number of routes, route length and walking distance
Kinable et al., 2014 [35]	BSS,RG	VC,SR,RT	Exact branch and price framework	Minimizing the routing costs
Michael Bogl al., 2015 [36]	BSS,RG,RS	VC,WD,WT	Heuristic solution framework allowing transfers	Minimizing the operational costs
Xiaopan et al., 2015 [37]	RG,RS	TW,RT	Exact mixed integer programming and two-stage metaheuristic method	Minimizing the number of routes and total number of buses
Cristiano et al., 2015 [6]	RG,RS	VC,TT,SR,WD	Mixed load approach	Minimizing the total traveled distance of a heterogeneous fleet

Table 2. Representation of various research in school vehicle tracking and monitoring

Study	Sensor type	Type of tracking considered	Nature of tracking	Goal
Anund et al., 2011 [38]	Active RFID	VLT	Lag time	To monitor bus location and providing bus time information to parents
Khaled et al., 2013 [39]	GPS	VLT	Real time	To smartly track the school bus and share the location info with parents
Zambada et al., 2015 [40]	GPS,accelerometer	VLT, VDBM	Real time	Increasing the safety of school bus monitoring through InterneT of things (IoT)

Table 3. Representation of various research in school student tracking and monitoring

Study	Sensor/Technology used	Type of tracking considered	Nature of tracking	Goal
Anund et al., 2010 [18]	RFID	SLT, IVA	Active	To track and monitor the school students inside the school bus
Saranya et al., 2012 [41]	GPS	SLT	Active	To track the location and emotional status of the student
Khaled et al., 2013 [39]	RFID	SLT	Passive	To track and monitor the student during their trip to and from school on school bus
Huang et al., 2014 [8]	GPS/Bluetooth	SLT	Active	To develop a mobile based child security monitoring system in school travel
Anwaar et al., 2015 [42]	RFID	SLT, IVA	Passive	To track the student location and monitoring bus boarding times
Peter et al., 2015 [43]	GPS/Heart rate	SLT, HM	Passive	To monitor the student physical activities from school to home travel

3.2.2 Vehicle-Driver Behaviour Monitoring (VDBM):

It is used to detect the vehicle and driver behaviour to find the vehicle Estimated Time of Arrival (ETA) and rash driving. This is accomplished through various speed sensors on the vehicle like accelerometer along with GPS [40]. Table II shows characteristics of school vehicle tracking and monitoring systems. The main focus in the table is the different types of vehicle tracking systems used in ISTS.

3.3 Student Tracking and Monitoring Systems

Similar to bus tracking, student tracking also employs similar technologies which are used to traverse the accurate placement of students. RFID is commonly employed for student tracking [42]. The student tracking system can be classified into two types: location tracking and health monitoring.

3.3.1 Student Location Tracking (SLT):

The most common technique used for student location tracking is the utilization of RFID tags. RFID tags can show the nature of tracking. There are two types: active and passive RFID [39]. An active RFID tag has its own power source. Passive RFID have a chip embedded, which withdraws power from the RFID scanner that emits electromagnetic waves. Students are also tracked using GPS embedded devices [8], [41] which share their location with all the stakeholders (i.e) school authority, bus drivers and parents. In-Vehicle Attendance (IVA) is part of the student tracking system in which the presence of students is determined through RFID tags. The school bus with a RFID reader is used to read student' tag [42]. When a student enters the vehicle, it is automatically recorded and it is considered as active registration. If a student manually registers, it is considered as passive registration.

3.3.2 Health Monitoring(HM):

Health is an important factor for student monitoring. It not only helps the parents to understand their children's attentiveness but also helpful during emergencies. Health monitoring is performed through a heart rate sensor which is worn by the student [43]. Table III represents the characteristics of school student tracking and monitoring systems. The table shows different types of student tracking systems used in ISTS.

4 ISTS Challenges

The implementation of various technologies (route planners, trackers, monitors) in the school transportation systems comes with many challenges which have to be resolved for the welfare of school children. A real-time school bus routing system has to be efficient and safe enough to transport the children. But considering all the safety aspects, selecting the school bus route is a challenging task. The routing problems get more complex when the nature of the problem changes (eg. single school to multiple schools). Moreover, the safety aspects considered have to be easy to embed into the existing routing system without compromising performance. For an example, in [45] the energy consumption of vehicles is considered as one of the constraint for the route and it is directly added to the routing software without reducing the performance of the existing system. Dynamic traffic navigation (re-routing) will be of progressive importance in future years [46]. Implementing an efficient and dynamic traffic safety routing in urban school transportation is a challenging task. Tracking the school vehicle in real-time without the GPS network lag is important. The vehicle tracker lets the parents and children to comfortably plan their journey to the bus stop. A recent study on improving GPS-based vehicle positioning [47] stated that the GPS technology based conventional localization techniques are not able to provide reliable and accurate positioning in all situations. Also, providing real-time access to the stakeholders without network latency is a challenging task. Smartphone based vehicle-driver monitoring [50], [51] may improve the existing school bus tracking system because of the embedded sensors they use and the easy implementation. However, customizing it for school bus transportation by considering all safety characteristics will be challenging. Many student tracking systems have been developed in which mostly employ radio frequency based devices. Recent studies in radiation exposure [48], [49] reported that children are more likely to be vulnerable than healthy adults to radio frequency electromagnetic radiation. So the development of children tracking system with less or no radiation based methods will reduce the risk of a child's vulnerability towards radiations which is challenging.

5 Conclusion and Future Directions

Millions of people use school transportation in their daily lives. Children are seen as vulnerable users of the road and there is demand for safe school transportation organizations. Several technologies have been evolved to increase safety and to avoid fatal injuries to children to and from school. This paper presented a review of major technologies and approaches used in school transportation, including route planning systems, vehicle – student monitoring and tracking systems. Each category is reviewed and a comparison was made between different systems.

The existing systems suffer from many limitations. Safety levels of the existing systems can be improved in several ways. Proper safety frameworks are required to avoid unexpected and fatal child injuries. The comparison made between routing problems in this study reveals that, most of the existing literatures focus on the economy and the shortest routes to carry students, but they do not regard the safety aspects of the routes as precedence. Identification of vulnerable routes and safety of the routes should be considered in future systems. GPS is commonly utilized in most of the school bus tracking systems. Tracking the school bus in real-time without network latency is important. Improvement in GPS accuracy and reduction in network latency can enhance the efficiency and reduce safety risks in school transportation. Tracking the driving behaviour of school bus drivers can help transportation departments to take the necessary action, thereby enhancing the quality of transportation.

Development of radiation free devices for school children tracking systems will reduce children expose to radiation. We aim to propose a framework for safe route planning and tracking of school transportation with improved safety and a reduced risk of accidents.

References

1. Kostas Kalogirou, Eleni Chalkia, Evangelos Bekiaris and Frederik Diederichs, "An application for the information of children according their school transportation", in procedia - Social and behavioral sciences, Elsevier, 2012, pp. 363 - 372.
2. UK Road safety data, https://data.gov.uk/dataset/road-accidents-safety-data, Accessed on Dec 2015.
3. Angela Harrison, "Road safety: Insurers show accidents near schools", BBC news, Aug 2013.
4. Vasumita s adarsh, ET bureau, "Startups like Ospox and North star offer safety solutions for school kids parents", Economic times of India, Aug 29, 2014.
5. Teresa Yuan, "New GPS tracking devices on Kent school buses", King 5 News, Jan 4, 2016.
6. C. M. Silva, J. F. M. Sarubbi, D. F. Silva, M. F. Porto, and N. T. R. Nunes, "A Mixed Load Solution for the Rural School Bus Routing Problem," IEEE 18th International Conference on Intelligent transportation systems, pp.1940-1945, 2015.
7. Faraj, M. F., Sarubbi, M., Silva, C. M., Porto, M. F., Tadeu, N., & Nunes, R, "A Real Geographical Application for the School Bus Routing Problem". IEEE 17th International Conference on Intelligent Transportation Systems, Qingdao, China, 2014, pp. 2762–2767.
8. Huang, Z., Gao, Z., Lu, H., Zhang, J., Feng, Z., & Xia, H. "A Mobile Safety Monitoring System for Children". 10th IEEE International Conference on Mobile Ad-Hoc and Sensor Networks, 2014, pp.323–328.
9. Mammen, G., Stone, M. R., Buliung, R., & Faulkner, G, "Putting school travel on the map: Facilitators and barriers to implementing school travel planning in Canada". Journal of Transport & Health, 2015, pp. 318-326.
10. Harrison, F., Burgoine, T., Corder, K., van Sluijs, E. M. F., & Jones, A, "How well do modelled routes to school record the environments children are exposed to?: A cross-sectional comparison of GIS-modelled and GPS-measured routes to school", International Journal of Health Geographics, 2014.
11. Falkmer, T., Horlin, C., Dahlman, J., Dukic, T., Barnett, T., & Anund, A, Usability of the SAFEWAY2SCHOOL system in children with cognitive disabilities", European Transport Research Review, pp. 127–137, 2014.
12. Riera-Ledesma, J., & Salazar-González, J. J., "A column generation approach for a school bus routing problem with resource constraints", Computers and Operations Research, pp. 566–583, 2013.
13. Yang, S.-H., & Hsiung, P.-A, "Innovative Application of RFID Systems to Special Education Schools", IEEE Fifth International Conference on Networking, Architecture, and Storage, pp. 299–304, 2010.
14. Rita M. Newton, Warren H. Thomas," Design of school bus routes by computer", Socio-Economic Planning Sciences, Elsevier, pp. 75-85, 1969.
15. Desrosiers, J., Ferland, J.A., Rousseau, J.-M., Lapalme, G., Chapleau, L., "An overview of a school busing system", Scientific Management of Transport Systems, pp. 235–243, 1981.
16. Braca, J., Bramel, J., Posner, B., Simchi-Levi, D., "A computerized approach to the New York City school bus routing problem", IIE Transactions, pp. 693–702, 1997.
17. Junhyuk Park, Byung-In Kim, "The school bus routing problem: A review", European Journal of Operational Research, Elsevier, pp. 311-319, 2010.
18. Anund, A., Dukic, T., Börsbo, B., & Falkmer, T., "Piloting smart safe school bus: exploration of security gains from implementation of a driver support system, additional technical equipment and intelligent bus stops", European Transport Research Review, pp. 157–163, 2010.
19. Anund, A., Dukic, T., Thornthwaite, S., & Falkmer, T., "Is European school transport safe?—The need for a "door-to-door" perspective", European Transport Research Review, pp. 75–83, 2011.
20. Byung-In Kim and Sangwon Jeong, "A comparison of algorithms for origin-destination matrix generation on real road networks and an approximation approach," Computers and Industrial Engineering, vol. 56, no. 1, pp. 70–76, 2009.
21. Riera-Ledesma J, Salazar-Gonza´lez JJ., "Solving a school bus routing problem", Odysseus 2006, third international workshop on freight transportation and logistics, Altea, Spain. pp. 285–8, 2006.
22. Schittekat P, Sevaux M, S¨ orensen K. "A mathematical formulation for a school bus routing problem", IEEE 2006 international conference on service systems and service management, Troyes, France, pp. 1552–7, 2006.
23. Riera-Ledesma J, Salazar-Gonza´lez JJ. "Solving school bus routing using the multiple vehicle traveling purchaser problem: a branch-and-cut approach", Computers & Operations Research, pp.391–404, 2012.
24. Bodin L, Berman L, "Routing and scheduling of school buses by computer", Transportation Science, pp.113–129, 1979.
25. Dulac G, Ferland JA, Forgues PA, "School bus routes generator in urban surroundings", Computers & Operations Research, pp.199–213, 1980.
26. Desrosiers J, Ferland JA, Rousseau JM, Lapalme G, Chapleau L, "Transcol: a multi-period school bus routing and scheduling system", TIMS Studies in the Management Sciences, pp.47–71, 1986.
27. Chapleau L, Ferland JA, Rousseau JM, "Clustering for routing in densely populated areas", European Journal of Operational Research, pp. 48–57, 1985.
28. Bowerman R, Hall B, Calamai P, "A multi-objective optimization approach to urban school bus routing: formulation and solution method", Transportation Research Part A, pp.107–23, 1995.
29. Schittekat, P., Kinable, J., Sörensen, K., Sevaux, M., Spieksma, F., & Springael, J, "A metaheuristic for the school bus routing problem with bus stop selection", European Journal of Operational Research, pp.518–528 , 2013.
30. J. Euchi and R. Mraihi, "The urban bus routing problem in the Tunisian case by the hybrid artificial ant colony algorithm," Swarm Evolutionary Computation, vol. 2, pp. 15–24, 2012.

Coach Travel Safety Analysis Matrix (CTSAM)

A tool for analysing safety of children travelling by coaches in the UK

Manoharan Ramachandran, Reza Sahandi, Simant Prakoonwit and Wajid Khan
Faculty of Science and technology
Bournemouth University
Bournemouth, United Kingdom
{mramchandran,rsahandi,sprakoonwit,wajid@bournemouth.ac.uk}

***Abstract*—Coach based school transportation is a less investigated area in the continent of United Kingdom. Though they are considered the safest mode of transport for children, coaches have a significantly high number of fatalities per accident. There are a limited number of studies which have implemented qualitative interviews to analyse the safety of children travelling in coaches but no standard methods were followed to prepare the questions for the interviews. There are no standard methods available to analyse the safety of children travelling in coaches in the UK. To rectify this issue, an interview guide called Coach Travel Safety Analysis Matrix is proposed in this paper. It is based on the Haddon Matrix which is used as a standard tool to analyze bus and coach accidents. The proposed matrix can be utilised to frame questions for the qualitative interviews to systematically analyse the safety of children travelling in the coaches in the UK. As this matrix is generic, it can also be used in continents other than the UK.**

Keywords—children safety; school transport; interview guide; CTSAM; haddon matrix;

I. Introduction

School transport through private coaches is critical for safety, as it involves children, the most vulnerable users[1]. Coach-based school transport in the UK is a less investigated area compared to the other modes of transport for school trips [2]. Though coaches are considered the safest mode of travel for children, they involve a high number of fatalities per accident [3][4]. A total of 371 coach accidents have been recorded between 2006 and 2015 in the UK (excluding Northern Ireland) as a result of which, 1191 children getting injured during the school trips [5]. The common contributory factors for these accidents, as reported, were driver errors and vehicle errors [6]. The UK government is aware of all these contributory factors and that's why they have strict regulations on operator compliance with the government safety policies. But, in the last year alone (2016), 137 coach operator licenses have been revoked in the UK, without public enquiry, due to operator non-compliance [7]. Thus, we can say that the accidents are happening not because of existing regulations, but due to coach operators' failure to follow those regulations which is also confirmed by the contributory factors for those accidents. This raises a question; are school transport through private coaches really safe or not? In England alone, more than 48000 school trips are carried out every year [8] of which, coaches are considered the most desirable mode of transport for children [9]. Based on the traffic commissioner reports, it is hard to assume that all the coach operators used for the school transport are safe and compliant. This situation puts the children's lives at risk and requires immediate attention. There are only few studies in the past wherein the qualitative research has been used as the methodology to identify the safety related issues in the school transport through coaches. But those studies didn't follow any standard method of preparing the questions for the interviews. So, there is a need for a standard framework or method to create questions for the qualitative interviews to analyse the safety of children travelling by coaches in the UK. This paper presents a systematic interview guide called Coach Travel Safety Analysis Matrix (CTSAM) which is based on Haddon Matrix. CTSAM will act as a standard tool for creating questions for qualitative interviews. The rest of the paper has been organised as follows: literature review on existing studies which focused on identification of safety issues through qualitative studies has been presented in Section II. Section III explains the CTSAM in detail and Section IV illustrates the real time evaluation of it. Conclusion and Future work is presented in the Section V.

II. Literature Review

There have been an increasing number of coach accidents involving children happening every year. Recent coach accidents [10]–[12] involving UK school children had alarmed the UK government and safety professionals to increase the safety standards to reduce the number of coach accidents and fatalities. In 2010, the Scottish government utilized the Transport Research Laboratory (TRL) to improve the existing safety guidelines, procedures and policies related to coach transport [13]. In-depth case studies were carried out to analyse the safety level of coach-based school transport and their effectiveness was analysed after 2 years from the commencement date [14]. Qualitative interviews were used as part of the in-depth case studies and there were no standard methods or guidelines followed to prepare the questions for the qualitative interviews. Other than the Scottish study, not many valid studies have been found in the existing literature that was carried out in the UK. So, we have expanded our literature search outside the UK to the European Union Countries which have similar laws compared to the UK and a related study is found. In 2012, a project called safeway2school was started in Sweden which focused on

978-1-5386-4304-4/18/$31.00 ©2018 Crown.

planning safe routes, providing active tracking facilities in school transport and real-time monitoring of coach and children which were developed for the schools in few European countries. To evaluate the effectiveness of the study, mixed method research was been carried out [15], [16]. But, no standard method or procedure is followed to create the questionnaire. Other than these studies, no other valid study has been found inside the Europe. So, to identify a common framework to create questions for qualitative interviews in the same context anywhere in the world, a broad literature search was employed.

Edmonston et al. [17] tried to provide safety recommendations for coach-based school transport for the New Zealand government by analysing the existing safety level through a systematic fashion. First, they reviewed the existing policies, practice and research related to safety of school transport, then they approached community groups to discuss about the school transport safety and confirmed the need for the extensive analysis of the safety of school transport in Queensland. To achieve this, they modified the Haddon Matrix [18] (a tool to analyse the bus accidents in detail) and created "school transport safety matrix" to improve school transport safety in Queensland. Though the matrix helped to achieve their goal, they only focused on creating the interview guide in terms of the coach crash. Other external factors were not considered in the matrix. Our idea is to follow their format to create a safety analysis matrix to improve the coach-based school transportation in the UK. The novelty in the proposed matrix, it considers all the internal and external factors not only in the context of coach crashes but also for the entire coach journey from beginning to end. It also helps to identify the needs of the stakeholders to improve the safety of school transport through coaches. This will help the researchers to gather vast amount of data in a systematic way by making sure all aspects of school-coach transport are covered. The following section will provides further details of the proposed matrix.

III. Coach Travel Safety Analysis Matrix (CTSAM)

Going by the accident statistics recorded in STATS19 [5], traffic commissioners' reports [7] and lack of literature on coach based school transport, it is apparent that there is a need for a further investigation of current safety of children travelling by coaches in the UK. To achieve this goal, we devised a holistic interview guide which we named as "Coach Travel Safety Analysis Matrix (CTSAM)". CTSAM can be used to investigate current coach travel safety and identify the needs and problems of stakeholders in coach-based school transport. Each trip may be classified into three phases, Pre – journey (before the trip), journey (during the trip) and post – journey (after the trip). These three phases have been divided based on the three different factors related to coach transportation, namely, Human/Host, Agent/Vehicle and Physical Environment. Inside the CTSAM, various topics related to school transportation with respect to the journey-phase and factor are listed. Table 1 shows the topics which are prepared based on the current coach-based school transport in the UK. School transport using coaches can basically be classified into two types; home to school transport and specific purpose transport (school trips) [19]. This interview guide can be utilized to analyse the safety of both the types of coach-based school transport.

5.1 Pre-Journey

This phase relates to all the activities which take place before the trip. Analysing pre – journey activities help to identify issues that arise before the trip. Topics in this phase help the investigators to identify the route cause for accidents and ways to prevent them. This phase covers topics which include accident awareness, safety measures taken, driver safety, children safety, vehicle safety, route safety and the operating environment.

5.2 Journey

This phase relates to all activities that take place during the trip, which include children safety, stakeholder communication, and issues faced during travel. By investigating the journey phase, internal/external issues that lead to a coach accident can be identified. It also helps in identifying the issues that may arise during the trip.

5.3 Post-Journey

This phase contains topics relates to all the activities that take place after the trip. Analysing post – journey activities helps the investigator to identify the stakeholder's experience of the trip. This phase covers topics, which include children safety, experiences, suggestions, issues & needs of the stakeholders and emergency procedures if vehicle meets with an accident. This phase helps the investigator to improve the coach service provided.

TABLE I. COACH TRAVEL SAFETY ANALYSIS MATRIX (CTSAM)

Journey sequence	Human/Host	Agent/Vehicle	Physical Environment
Pre Journey	• Accident Awareness • Safety Measures • Driver Check • Children Safety	• Vehicle Safety • Safety Measures • Children Safety	• Coach Operating Environment and Procedures • Route Safety • Children Safety
Journey	• Children Safety • Children Behavior Issues • Stakeholder Communication	• Problems During Travel • Vehicle Issues	• Environment and Other Problems
Post Journey	• Children Safety • Communication Problems • Preventions, Suggestions & Future Enhancements	• Emergency Procedures	• Pickup/Drop Bus Stop Issues

TABLE II. CTSAM EVALUATION

Journey sequence	Human/Host	Agent/Vehicle	Physical Environment
Pre-Journey	**Accident Awareness:** 1. Are you aware of any school transport related crashes in your school or any other schools? (T, S,P,C, D) 2. What might be the possible cause of school transport accidents? (T, S, P, C, D) **Safety Measures:** 1. What are all the safety measures taken in your council for the school transportation (bus stops, route planning, campaigns)? (T) 2. Are there any safety protocols followed while waiting at the bus stop, boarding into the coach, travelling in the coach and getting down from the coach? (T, S,C, D) 3. How strictly are the guidelines are followed in school transportation? (T, S, P, C, D) **Driver Check:** 1. Who will verify the drivers CRB, license and driving hours? (T, S, C, D) 2. Do you prove any special training for the school coach drivers? (C) 3. Do you have any assessment of driver physical and mental health? Would you tell more about it? (C) **Children Safety:** 1. Are children provided with any safety briefing before using the school transportation for the first time? (C)	**Vehicle Safety:** 1. How do you know that the coaches are in good condition? Do you have any daily checks? (T, S, C, D) 2. Who usually checks MOT, Insurance, safety checks and general condition? (T, S, P, C, D) 3. Do the schools check any of the above? OR does the council verify any of the above? (T, S, P, C, D) 4. How do you know that the companies are adhering to these guidelines? (T, S, P, C, D) 5. Are the selected vehicles always safe? Could you a say few words on how safe they are? (T, S, P, C, D) 6. Are there any restrictions on what you supply? (e.g.) age of vehicle? (C) **Safety Measures:** 1. Which safety measures (technical, educational, bus stops, road design) were taken on the coach concerning school transportation? (C, D) **Children Safety:** 1. How safe are the children while getting onto the coach? (T,S,P,C,D)	**Coach Operating Environment and Procedures** 1. What kind of road constraints have been considered for school transportation? E.g. [40km/h] zones. (C, D) 2. How important is it to have proper Student, Driver education? (C, D) 3. Have you had a special training as a coach driver for school transportation? If yes, please describe the training. (D) **Route Safety:** 1. What safety measures (technical, educational, bus stops, road design) were taken on your route concerning school transportation? (T, D) 2. Who is in-charge of selecting the coach routes? (T, S, P, C, D) 3. Are the selected routes always safe? Could you say a few words on how safe they are? (T, S, P, C, D) 4. Are you using any software for route planning or is it done manually? (T, S, C) 5. Do you use any safety framework for school transportation? (T, S, C) 6. What are all the constraints that have been considered in route planning? (T, S, C) 7. Have any safety related constraints been considered in planning the routes? (T, C) 8. Are parents involved in route planning? (T, C) **Children Safety:** 1. How safe are the children are at the bus stops? (T, S, P, C, D)
Journey	**Children Safety:** 1. How safe are the children while travelling on the coach? (T, S,P,C, D) 2. How do you make sure that children are wearing the seatbelt on the coach? (C, D) 3. How do you react when a student is coming out of the seat or disturbing you while driving or fighting with each other? Do you ever face such problems in your driving experience? (D) **Stakeholder Communication:** 1. Do you communicate or would you like to communicate for safety reasons with the following actors during travel? (D) a. School transport department? Why? b. Parents e.g. if a child does not appear or has (health) problems? c. Authorities e.g. you detect a “nearly accident” and want to report it? (D) 2. What kind of technology do you use to communicate with parents and school transport department? (D)	**Stakeholder Communication:** 1. How important it is to let the parents know about the school coach location (Phone call or GPS)? (D) **Problems During Travel:** 1. What unsafe/risky situations have you experienced while driving the coach? Please describe the situation. What increases the safety in coaches for school transportation? (D) 2. What unsafe/risky situation have you experienced driving on a particular route? Are all the short routes safe? (D) 3. What are all the problems that arise in the short/long routes? (D) 4. What defines a safe route in your opinion? (D)	**Problems:** 1. How do you reroute during travel if a normal route is blocked due to road work or accident? (D) 2. How to you mitigate the weather problems arise during the journey? (D)

Post Journey	**Children Safety:** 1. How safe are the children while getting down from the coach? (T, S, P, C, D) **Problems:** 2. What kind of experiences (good/bad) from coach/bus stop are usually reported by the coach driver? (T, S, P, C) 3. What kind of experiences (good/bad) from coach/bus stop are usually reported by the pupils (students)? (T, S, P, C) 4. What kind of experiences (good/bad) from coach/bus stop are usually reported by parents? (T, S, C) 5. What kind of risks are usually faced by the drivers/students during the travel that are reported to the management? (T, S, P, C) 6. What kind of experiences (good/bad) are usually reported by the school? (C, P) **Preventions, Suggestions & Future Enhancements:** 1. What are all the safety aspects that must be on a route for school transportation to prevent accidents? (T, C, D) 2. What is your suggestion to enhance the safety of school travel? (T, S, P, C, D) 3. What are the criteria that can be considered during the safe school route planning? (T, S, P,C, D) 4. What kind of system/technology do you expect that will improve the safety in school travel? (T, S, P, C, D) 5. Is there anything important concerning school transportation, that wasn't spoken about? (T, S,P,C, D)	**Emergency Procedures:** 1. What kind of safety measures are in place if a school vehicle meets with an accident? (T,S,C,D)	

Legends:
T – Town Council – Local Authorities – Road Safety Analysts
S – School head teachers/ School transport in charge
P – Parents
C – Coach providers
D – Coach Drivers

IV. CTSAM Evaluation

To evaluate the CTSAM, we have incorporated it into our research [19], [20] in order to study the safety of children in coach-based school transport safety in Luton Borough Council. Using the Table I, questions related to the coach-based school transport were prepared and validated by experienced stakeholders (coach operators, drivers, school headmasters and council transport officers) using pilot studies before initiating the actual interviews. Pilot interviews were conducted not only to validate the topics and questions but also to amend the topics and questions where ever necessary. After the questions were validated, CTSAM was utilized for the main stakeholders' (parents, head masters, coach operators, coach drivers, council transport officers and road safety analysts) qualitative interviews. CTSAM helped to cover all the aspects of school transport using coaches in Luton Borough Council. It helped to identify the safety related issues and requirements related to coach-based school transport. It also helped to identify an important knowledge gap present between the stakeholders in Luton Borough Council. The results of the study will be published as a separate paper. Results of our qualitative survey proved that CTSAM has achieved its intended goal of analysing safety of children travelling in coaches, in a systematic way.

V. Conclusion and Future Work

Safety of children is a critical issue which has to be addressed effectively. Coach-based school transport is a less investigated area compared to the other modes of transport to school in the UK. From the literature it is clear that a systematic study has to be done to identify the safety level of coach-based school transport. Existing studies didn't follow any standard models to prepare the questions for the qualitative surveys. There are no standard models available which ensures the safety of children travelling in coaches. This paper has presented a holistic interview guide to prepare questions for the qualitative study in systematic manner. Evaluation showed that CTSAM helped to achieve its intended purpose by producing useful and new results. As our future work, CTSAM will be implemented in other councils in the UK to compare the safety results of various councils in the UK.

Acknowledgment

This research is funded by Bournemouth University and County Coaches, United Kingdom.

References

[1] K. Kalogirou, E. Chalkia, E. Bekiaris, and F. Diederichs, "An Application for the Information of Children According their School Transportation," Procedia - Soc. Behav. Sci., vol. 48, pp. 363–372, 2012.

[2] M. Ramachandran, R. Sahandi, S. Prakoonwit, and W. Khan, "Intelligent Safety Transport Framework for Schools : A Review of Route Planning and Tracking Systems," vol. 7, 2016.

[3] P. Albertsson, U. Björnstig, and T. Falkmer, "The Haddon matrix, a tool for investigating severe bus and coach crashes," Int. J. Disaster Med., vol. 1:2, s. 10, pp. 109–119, 2003.

[4] I. Doohan and B. I. Saveman, "Impact on life after a major bus crash - a qualitative study of survivors' experiences," Scand. J. Caring Sci., vol. 28, no. 1, pp. 155–163, 2014.

[5] DfT, "Department for Transport (Great Britan) Road Safety Data - Datasets," Data.Gov.Uk, 2016. [Online]. Available: https://data.gov.uk/dataset/road-accidents-safety-data. [Accessed: 17-Nov-2016].

[6] DfT, "Department for Transport (Great Britan) : Contributory factors for reported road accidents," Data.Gov.Uk, 2016. [Online]. Available: https://www.gov.uk/government/statistical-data-sets/ras50-contributory-factors. [Accessed: 17-Nov-2016].

[7] T. Commissioners, "Traffic Commissioners' Annual Reports," gov.uk, 2016. [Online]. Available: https://www.gov.uk/government/collections/traffic-commissioners-annual-reports.

[8] R. Drake, "Schools, pupils and their characteristics," Data.Gov.Uk, 2016. [Online]. Available: https://www.gov.uk/government/statistics/schools-pupils-and-their-characteristics-january-2016. [Accessed: 17-Nov-2016].

[9] D. G. Move, "Comprehensive Study on Passenger Transport by Coach in Europe," no. April, 2016.

[10] J. Espinoza, "Coach driver killed as bus carrying British schoolchildren crashes in Belgium," telegraph.co.uk, 28-Jun-2015.

[11] R. Bishop and S. Campbell, "France coach crash: Two British school kids critically injured and 13 hurt in motorway accident," mirror.co.uk, 23-Jul-2016.

[12] A. Fox and R. Burnett, "British teen crawled through bus wreckage with a broken back to escape Spain crash that killed 13 students," mirror.co.uk, 21-Mar-2016.

[13] N. Kinnear and L. Smith, "A Guide to Improving School Transport Safety: Casualty risk, responsibilities and legal requirements, and ten ways to reduce risk on the school journey," 2010.

[14] R. Hutchins and N. Kinnear, "PUBLISHED PROJECT REPORT PPR648 Review of ' A Guide to Improving School Transport Safety ' R Hutchins and N Kinnear," 2012.

[15] E. Aigner-Breuss, M. Pilgerstorfer, A. Anund, T. Dukic, E. Chalkia, C. Ferrarini, R. Montanari, J. Wacowska, D. Jankowska, F. Diederichs, and A. Pauzie, "Comparison and analysis of user and stakeholder needs across different countries," no. September, 2010.

[16] A. Anund, T. Dukic, S. Thornthwaite, and T. Falkmer, "Is European school transport safe?—The need for a 'door-to-door' perspective," Eur. Transp. Res. Rev., vol. 3, no. 2, pp. 75–83, 2011.

[17] C. J. Edmonston and M. C. Sheehan, "' Safe school travel is no accident !' - Applying the Haddon Matrix to school transport safety," 2001.

[18] H. William, "A logical framework for categorizing highway safety phenomena and activity.," Journal of Trauma, vol. 12. pp. 193–207, 1972.

[19] M. Ramachandran, R. Sahandi, S. Prakoonwit, W. Khan, and S. A. Mohd Selamat, "A Safety Transport Model for Validation of UK Coach Operators for School Journeys," in Intelligent Transport Systems – From research and development to the market uptake, 2017 (accepted).

[20] M. Ramachandran, R. Sahandi, S. Prakoonwit, and W. Khan, "Mathematical Model for Safety Score Calculation for Validation of Coach Operators in the UK," in Intelligent Transport Systems – From research and development to the market uptake, 2017 (accepted).

An Intelligent Recommendation Model for Coach Operators

Manoharan Ramachandran, Reza Sahandi, Simant Prakoonwit and Wajid Khan
Faculty of Science and technology
Bournemouth University
Bournemouth, United Kingdom
{mramchandran,rsahandi,sprakoonwit,wajid@bournemouth.ac.uk}

***Abstract*— In recent years, Intelligent Transportation Systems (ITS) have grown rapidly by solving problems in the transport industry through state of the art solutions. Coach Operators' non-compliance is an issue in the UK, which require attention. Last year alone, 137 coach operator licenses have been revoked without public enquiry, equating to invalidating 11 licenses on average every week. The main reasons for this problem is the coach operators' negligence and failing to respond to safety issues associated with their fleet. An Intelligent Recommendation Model for Coach Operators is proposed. The model by analysing the track record of Operator's Compliance Risk Score (OCRS), provides recommendations to improve safety. An initial evaluation shows that the model has achieved its intended purpose and provided accurate and suitable recommendations to the two operators to improve safety of their fleets.**

Keywords—Intelligent recommendation model; intelligent system; coach operator safety; operator non-compliance; coach transport;

I. Introduction

Transport has become an essential part of any society and its economy for its sustainable functioning. Recent advances in Intelligent Transportation Systems (ITS) have taken road transport to the next level in terms of safety, accessibility, reliability and communication [1]. ITS advancements in coach based road transport has led to the creation of vehicle routing, vehicle monitoring and driver monitoring systems [2]. An ITS typically consists of elements such as electronics, a control system, communication, sensing, robotics, signal processing and information systems [3]. Even though ITS tries to solve current problems in the transport industry, there are still many issues that need to be solved. Coach operator's non-compliance in the UK is one of them which have created a major safety problem in the transport industry today. There are more than 9000 coach operators in the UK [4]. In the last 10 years, 698 coach operator licenses have been revoked without public enquiry due to non-compliance [5]. Last year alone, 137 coach operator licenses have been revoked without public enquiry. These statistics have serious impact on coach based school transportation. In the last 10 years 1191 children have been injured in 371 coach crashes [6]. Coach operators have not been paying attention to safety issues and problems which existed in their own fleets [7]. In an attempt to overcome this problem, an intelligent recommendation model which can be used to analyse operator's Compliance Risk Score (OCRS) is proposed. The model provides safety recommendations to the operator based on the data collected. The model consists of three parts. Part one: a comparison of average safety scores of coach operators at the county (local, regional and national levels. Part two: OCRs analysis and safety scores of coach operators over three years. Part three: recommendations to improve fleet safety. To explore its accuracy, the model was tested using real data from two coach operators. The results show that the model has achieved the objectives and can provide accurate recommendations to coach operator on how to improve their fleets' safety. This paper is arranged as follows, section II gives an over view of the existing literature, Section III explains how the OCRS system works and section IV describes the intelligent recommendation model. Finally in Section V, conclusion and future work are discussed.

II. Literature Review

Coach operator's non-compliance is a critical issue which have to be addressed effectively. Coach transport's safety is critical as it has potential for high fatalities per accident, compared to the other modes of ground transport. This is even worse in coach based school transport as it involves children who are most vulnerable users of them [8]. There is not enough literature available addressing the coach operator non-compliance problem. There are only limited studies which addressed the safety of coach transport in the UK [9]–[11]. Coaches in the UK are regulated by the Driver and Vehicle Standards Agency (DVSA). Under the DVSA there are also traffic commissioners for each region who are responsible for licensing and regulations of public service vehicles. Coach operators have to strictly follow the regulations laid down by the DVSA. Coaches might be stopped by the DVSA for road side inspections. DVSA uses a system known as the Operator Compliance Risk Score (OCRS) to decide which vehicle to inspect. If a coach operator is found guilty for serious regulation offenses, its license will be revoked with or without a public enquiry.

To understand the safety operation level of coach operators in the UK, particularly for school based journeys, a qualitative survey was conducted in Luton Borough Council (UK). The full result of the survey will be published in due course. During this survey, when schools were asked on how they ensure that their students are travelling safe, they indicated that they trust the coach operators. But, based on the traffic

978-1-5386-4304-4/18/$31.00 ©2018 Crown.

commissioner reports, it is hard to assume that the coach operators are always compliant with the government regulations and safe. The Department of Transport has identified negligence about the government regulations and lack of proper care of the fleet as reasons for the operators' non-compliance [7]. To avoid this problem and to help the operators to stay compliant with the government regulations, the Vovlo company has created a system [12]. However, the system focuses on road worthiness, traffic enforcement, monitoring and safety of the fleet. But, it only applies to Volvo vehicles.

There are no studies which provide guidance and assistant to operators to improve compliance. This paper proposes a model to help the operators to improve their safety scores. The model, by analysing the operator's OCRS provides recommendations to improve safety of the operator's fleet. The detailed explanation of the OCRS system and the model are discussed in the next section.

III. Operator Compliance Risk Score (OCRS)

In the UK, each coach operator receives an Operator Compliance Risk Score (OCRS) which reflects the safety level operated by its fleet. The OCRS is used by the Vehicle Standards Agency (DVSA) to decide whether a vehicle should be stopped for safety inspection. If the OCRS is high, it is more likely for a vehicle to be stopped. There are three types of OCRS: Roadworthiness OCRS (vehicle first use checks, annual checks and road side inspections), Traffic OCRS (drivers' hours checks and tachograph checks) and Combined OCRS (total roadworthiness and traffic points divided by total number of events). OCRS is updated every week by a re-scoring process. For Each OCRS type, there are 4 individual bands, Green (Low – risk operator), Amber (Medium risk operator), Red (High – risk operator) and Grey (unknown operator) [13].

An operator is given a Grey OCRS, if it is either new or its vehicle is yet to be taken for the checks. OCRS bands are decided based on the points operators have received during inspections for their fleets' maintenance and safety checks by DVLA. Figure 1 shows the OCRS band scoring guide defined by the UK government. Depending upon the OCRS collected over a 3 year rolling period, the base score for an operator is calculated as shown in the Figure 2. The official weighting factors for the calculation of a base score is, Year 1 – 1, Year 2 – 0.75 and Year 3 – 0.5 [13].

OCRS band	Roadworthiness	Traffic	Combined
Green	10 defect points or below	5 offence points or below	10 defect points or below
Amber	Between 11 and 25 defect points	Between 6 and 30 offence points	Between 11 and 25 defect points
Red	26 defect points or over	31 offence points or over	26 defect points or over
Grey	No score	No score	No score

Fig. 1. OCRS Band Scoring Guide

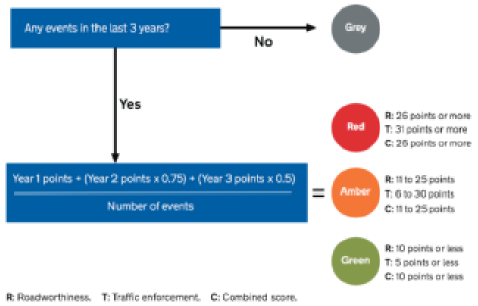


Fig. 2. Operator Base Score Calculation

IV. Intelligent Operator Recommendation Model

The intelligent recommendation model consists of five steps as shown in the Figure 3. They include data acquisition; data processing; local, regional and national safety score comparison; 3 year OCRS analysis and safety scores; and recommendations to improve fleet's safety scores.

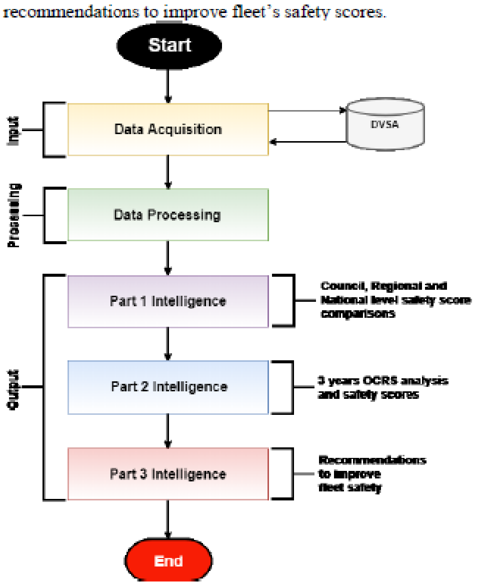


Fig. 3. Intelligent Operator Recommendation Model

A. Data Acquisition

The OCRS data for a coach operator along with the roadworthiness points and traffic points are obtained from the DVSA. If a coach operator is in the Red band, the operator must have received more than 26 defects points and 31 offence points. The complete list of points for defects and offence may be found in [13].

B. Data Processing

Once the relevant data for a coach operator is collected, it is processed for analysis. The OCR scores are updated every week. By analyzing the combined OCR scores over the years, they can reveal the fleet's performance and maintenance during the period time. To analyse the possible OCRS combinations for an operator over three years, it is necessary to consider all the possible combinations and sort them in most safe to least safe order. Table I shows the possible combined OCRS for a 3 years period (α – Year 1, β – Year 2 and μ – Year 3 - is the present year). To sort them in safety order, safety scores are used. To calculate the safety score, Equation 1 is used. Safety score is calculated based on the weighted average where year 1, 2 and 3 are multiplied with 0.5, 0.75 and 1 weights respectively (these weights are based on the UK government weighting system [14]. Depending on the calculated values, OCRS bands will be: 3 = Green, 2= Amber and 1 = Red. For an example let's take first row as example, Safety Score = (3*0.5) + (3*0.75) + (3*1) = 6.75. Equation 1 is repeated for all the combinations and safety scores are calculated. Some of the combinations will have same safety score as shown in the Table I. To break the tie, recent year OCR score is given with priority. For an example, No. 4 and No. 5 have the same safety score but No. 4 is given with higher priority because the present year (Year 3) OCRS is Green compared to the No.5 Amber. To show the trends and ties, values are color coded as shown in the Table I.

$$\text{Safety Score} = (\alpha * 0.5) + (\beta * 0.75) + (\mu * 1) \qquad (1)$$

For Part 3 intelligence, Table II is prepared which shows the possible combinations of roadworthiness OCRS and traffic OCRS which reflects the safety level of vehicles and drivers. For an example, if an operator has Amber for traffic offences and Green for roadworthiness, then possibly the operator's vehicles are average and drivers are good. Using the Table II, the category for the Coach Operator can be identified. Based on this category safety recommendations are provided (Part 3).

C. Part 1 Intelligence – Local to National Level Safety Score Comparision

Based on the safety scores calculated using the Table I, it is possible to measure safety level of an operator. Using the same formula, safety scores for all the operators in the county can be calculated. Based on the safety scores of all the operators at county level, regional level and national level, ranks can be calculated. Following is the logical code for the safety score comparison.

Logical Code:

```
Begin
//council rank calculation
If (all the safety scores of operators in a council is calculated)
then
{
Arrange the safety scores in descending order;
Calculate the ranks for the operators inside the council;
}
//Regional rank calculation
If (all the safety scores of operators in a region is calculated)
then
{
Arrange the safety scores in descending order;
Calculate the ranks for the operators inside each council;
Compare the ranks of operators in each council;
Find council average and compare it with other councils;
}
//National rank calculation
If (all the safety scores of operators in the nation are
calculated)
then
{
Arrange the safety scores in descending order;
Calculate the ranks for the operators inside each council;
Compare the ranks of operators in each council;
Find council average and compare it with other councils;
Find the average of each region and compare it with other
regions;
}
End
```

D. Part 2 Intelligence – 3 years OCRS analysis and safety scores

Part 2 intelligence helps to observe the trends over a 3 years period. It also provides the current status of the fleet and recommendations to improve the overall safety of it. This will be helpful to see whether an operator is improving the safety of the fleet or doing the exact opposite. Table III shows the OCRS trends over the last 3 years period. Safety scores range from 1.875 to 6.75 marking least safe to most safe operator.

E. Part 3 Intelligence – Recommendations to Improve Fleet Safety

To provide the safety recommendations, operator roadworthiness OCRS and traffic OCRS is used. Safety recommendations are provided based on the offenses an operator is committed. The offenses data is collected as part of the data acquisition process. Using the Table II combinations, the possible combined OCRS and the possible defects that might have occurred are listed along with all possible recommendations as shown in the Table IV. Based on the data gathered, the accurate safety recommendation is provided.

TABLE I. POSSIBLE THREE YEARS OCRS COMBINATIONS WITH SAFETY SCORES

S.No.	Year 1 (α)	Year 2 (β)	Year 3 (μ)	Safety Score
1	green	green	green	6.75
2	amber	green	green	6.25
3	green	amber	green	6
4	red	green	green	5.75

5	green	green	amber	5.75
6	amber	amber	green	5.5
7	green	red	green	5.25
8	amber	green	amber	5.25
9	red	amber	green	5
10	green	amber	amber	5
11	amber	red	green	4.75
12	red	green	amber	4.75
13	green	green	red	4.75
14	amber	amber	amber	4.5
15	red	red	green	4.25
16	green	red	amber	4.25
17	amber	green	red	4.25
18	red	amber	amber	4
19	green	amber	red	4
20	amber	red	amber	3.75
21	red	green	red	3.75
22	amber	amber	red	3.5
23	red	red	amber	3.25
24	green	red	red	3.25
25	red	amber	red	3
26	amber	red	red	2.75
27	red	red	red	1.875

TABLE II. POSSIBLE COMBINATIONS OF ROADWORTHINESS AND TRAFFIC AND THEIR OUTCOMES

		Roadworthiness		
		Green	***Amber***	***Red***
Traffic	***Green***	Vehicles: G Drivers: G (Less risk operator)	Vehicles: A Drivers: G	Vehicles: B Drivers: G
	Amber	Vehicles: G Drivers: A	Vehicles: A Drivers: A (Medium risk operator)	Vehicles: B Drivers: A
	Red	Vehicles: G Drivers: B	Vehicles: A Drivers: B	Vehicles: B Drivers: B (High risk operator)

Vehicle and Driver Condition - G – Good, A – Average, B – Bad

V. CONCLUSION AND FUTURE WORK

Coach transport is safety critical as it involves more fatalities per accident compared to the other modes of land transport. Operator non-compliance in the UK is an issue which has to be solved effectively. In this paper an intelligent safety recommendation model is proposed. An initial evaluation of the model shows the recommendations provided have been accurate. As our future work, a machine learning algorithm will be implemented to enhance the recommendations to operators and further improve safety.

Acknowledgment

This research is funded by County Coaches and Bournemouth University.

References

[1] T. Zhu and Z. Liu, "Intelligent Transport Systems in China: Past, Present and Future," 2015 Seventh Int. Conf. Meas. Technol. Mechatronics Autom., pp. 581–584, 2015.

[2] M. Ramachandran, R. Sahandi, S. Prakoonwit, and W. Khan, "Intelligent safety transport framework for schools: A review of route planning and tracking systems," in MATEC Web of Conferences, 2016, vol. 81.

[3] L. Figueiredo, I. Jesus, J. a. T. Machado, J. R. Ferreira, and J. L. M. De Carvalho, "Towards the development of intelligent transportation systems," ITSC 2001. 2001 IEEE Intell. Transp. Syst. Proc. (Cat. No.01TH8585), pp. 1206–1211, 2001.

[4] T. Commissioners, "Traffic Commissioners' Annual Reports," gov.uk, 2016. [Online]. Available: https://www.gov.uk/government/collections/traffic-commissioners-annual-reports.

[5] T. Commissioners, "Traffic Commissioner PSV notices and proceedings," Data.Gov.Uk, 2016. [Online]. Available: https://www.gov.uk/government/collections/traffic-commissioner-notices-and-proceedings. [Accessed: 21-Nov-2016].

[6] DfT, "Department for Transport (Great Britan) Road Safety Data - Datasets," Data.Gov.Uk, 2016. [Online]. Available: https://data.gov.uk/dataset/road-accidents-safety-data. [Accessed: 17-Nov-2016].

[7] DfT, "Department for Transport (Great Britan) : Contributory factors for reported road accidents," Data.Gov.Uk, 2016. [Online]. Available: https://www.gov.uk/government/statistical-data-sets/ras50-contributory-factors. [Accessed: 17-Nov-2016].

[8] M. Ramachandran, R. Sahandi, S. Prakoonwit, W. Khan, and S. A. Mohd Selamat, "A Safety Transport Model for Validation of UK Coach Operators for School Journeys," Intell. Transp. Syst. – From Res. Dev. to Mark. uptake, 2017.

[9] The Scottish Government, Scotland's Road Safety Framework to 2020. 2009.

[10] J. A. Van Ristell, "INVESTIGATING THE IMPACTS OF POLICY By," no. November, 2011.

[11] J. a. Van Ristell, M. a. Quddus, M. P. Enoch, C. Wang, and P. Hardy, "Quantifying the impacts of subsidy policies on home-to-school pupil travel by bus in England," Transportation (Amst)., vol. 42, no. 1, pp. 45–69, 2014.

[12] V. Trucks, "operator compliance," 2013.

[13] DVSA, "Use the Operator Compliance Risk Score (OCRS) system," gov.uk, 2016. .

[14] DVSA, "Use the Operator Compliance Risk Score (OCRS) system," gov.uk, 2016. [Online]. Available: https://www.gov.uk/guidance/use-the-operator-compliance-risk-score-ocrs-system. [Accessed: 30-Jul-2017].

TABLE III. THREE YEARS OCRS WITH SAFETY SCORES

Year 1	Year 2	Year 3		Analysis	Recommendation
green	green	green	6.75	Your fleet Maintenance is fabulous over last 3 years	Keep up the good work
amber	green	green	6.25	Your fleet Maintenance is fabulous over last 2 years	Keep up the good work
green	amber	green	6	Your fleet Maintenance is good	Keep up the good work
red	green	green	5.75	Your fleet Maintenance is fabulous over last 2 years	Keep up the good work
green	green	amber	5.75	Your fleet Maintenance is fair	Please check the previous recommendation section
amber	amber	green	5.5	Your fleet maintenance is good	Keep up the good work
green	red	green	5.25	Your fleet Maintenance is good	Keep up the good work
amber	green	amber	5.25	Your fleet Maintenance is fair	Please check the previous recommendation section
red	amber	green	5	your fleet Maintenance is fabulous and improved over the last 3 years	Keep up the good work
green	amber	amber	5	Your fleet Maintenance is fair	Please check the previous recommendation section
amber	red	green	4.75	Your fleet Maintenance is good	Keep up the good work
red	green	amber	4.75	Your fleet Maintenance is fair	Please check the previous recommendation section
green	green	red	4.75	Your fleet Maintenance is bad this year	Please check the previous recommendation section
amber	amber	amber	4.5	Your fleet Maintenance is average over last 3 years	Please check the previous recommendation section
red	red	green	4.25	Your fleet Maintenance is good this year compared to previous years	Keep up the good work
green	red	amber	4.25	your fleet Maintenance is fair and improving	Please check the previous recommendation section
amber	green	red	4.25	Your fleet Maintenance is bad this year	Please check the previous recommendation section
red	amber	amber	4	Your fleet Maintenance is fair over last 2 years	Please check the previous recommendation section
green	amber	red	4	Your fleet Maintenance is bad and degraded over last 3 years	Please check the previous recommendation section
amber	red	amber	3.75	Your fleet Maintenance is fair	Please check the previous recommendation section
red	green	red	3.75	Your fleet Maintenance is bad	Please check the previous recommendation section
amber	amber	red	3.5	Your fleet Maintenance is bad	Please check the previous recommendation section
red	red	amber	3.25	Your fleet Maintenance is poor but improved this year	Please check the previous recommendation section
green	red	red	3.25	Your fleet Maintenance is very bad	Please check the previous recommendation section
red	amber	red	3	Your fleet Maintenance is bad	Please check the previous recommendation section
amber	red	red	2.75	Your fleet Maintenance is very bad	Please check the previous recommendation section
red	red	red	1.875	Your fleet Maintenance is very worst	Please check the previous recommendation section

TABLE IV. RECOMMENDATIONS FOR POSSIBLE OCRS COMBINATIONS

Roadworthiness and Traffic OCRS combination	Possible combined OCRS	Roadworthiness and Traffic OCRS Score	Reason for the score	Recommendation
Roadworthiness- Green Traffic - Green	Green	Vehicles: Good Drivers: Good Less risk operator	-	Keep up the good work
Roadworthiness- Amber Traffic - Green	Amber	Vehicles: Average Drivers: Good	Defect No. 4 or 10	If it is No. 4 – Please ensure that, daily walk around checks are carried out properly and the defects identified were rectified. If it is No. 10 – Please double check your vehicle for any defects before you go for vehicle annual test.
Roadworthiness- Red Traffic - Green	Red	Vehicles: Bad Drivers: Good	Defect No. 1 or 2 or 3 or 5 or 6 or 7 or 8 or 9	If it is No. 1, 3, 5, 7 and 10 – Please maintain your vehicle's tyres, brakes and steering properly and make sure daily safety checks, weekly and annual checks are carried out properly. If it is No. 2, 4, 6 and 8– Please make sure daily walk around check and weekly maintenance checks are carried out properly.
Roadworthiness- Green Traffic - Amber	Green	Vehicles: Good Drivers: Average	-	
Roadworthiness- Amber Traffic - Amber	Amber	Vehicles: Average Drivers: Average	Defect No. 4 or 10	If it is No. 4 – Please ensure that, daily walk around checks are carried out properly and the defects identified were rectified. If it is No. 10 – Please double check your vehicle for any defects before you go for vehicle annual test.
Roadworthiness- Red Traffic - Amber	Red	Vehicles: Bad Drivers: Average	Defect No. 1 or 2 or 3 or 5 or 6 or 7 or 8 or 9	If it is No. 1, 3, 5, 7 and 9 – Please maintain your vehicle's tyres, brakes and steering properly and make sure daily safety checks, weekly and annual checks are carried out properly. If it is No. 2, 4, 6 and 8– Please make sure daily walk around check and weekly maintenance checks are carried out properly.
Roadworthiness- Green Traffic - Red	Green	Vehicles: Good Drivers: Bad	-	
Roadworthiness- Amber Traffic - Red	Amber	Vehicles: Average Drivers: Bad	Defect No. 4 or 10	If it is No. 4 – Please ensure that, daily walk around checks are carried out properly and the defects identified were rectified. If it is No. 10 – Please double check your vehicle for any defects before you go for vehicle annual test.
Roadworthiness- Red Traffic - Red	Red	Vehicles: Bad Drivers: Bad High risk operator	Defect No. 1 or 2 or 3 or 5 or 6 or 7 or 8 or 9	If it is No. 1, 3, 5, 7 and 9 – Please maintain your vehicle's tyres, brakes and steering properly and make sure daily safety checks, weekly and annual checks are carried out properly. If it is No. 2, 4, 6 and 8– Please make sure daily walk around check and weekly maintenance checks are carried out properly.

A Safety Transport Model for Validation of UK Coach Operators for School Journeys

Manoharan Ramachandran(✉), Reza Sahandi, Simant Prakoonwit, Wajid Khan, and Siti Aishah Mohd Selamat

Department of Science and Technology, Bournemouth University, Bournemouth, UK
{mramchandran, rsahandi, sprakoonwit, wkhan, aishah}@bournemouth.ac.uk

Abstract. Coaches are considered to be one of the safest modes of transport for children in the UK. In the last 10 years alone, 1191 children were injured in 371 coach crashes. Though the government has strict regulations to maintain road worthiness of the coaches, operator non-compliance was the major reason for these accidents. In last year alone, 137 coach operator licenses have been revoked due to operator non-compliance in the UK. Currently, there is no process to reliably mitigate the safety risks of children travelling by coaches. This has created a requirement to validate all the coach operators before using their coaches for school trips. This paper proposes a novel safety model for validation of coach operators prior to commencement of coach journeys.

Keywords: School transport · School trips · Children safety · Coach accidents Operator non-compliance · Coach hires

1 Introduction

Safety in transport is concerned with the protection of life by regulating, managing and developing technology for all forms of transport. People use transport for day-to-day activities such as school, work and business movements or for social and leisure purposes. Safety in school transport systems is critical as it involves children, who are the most vulnerable users [1]. Every year, schools in England alone makes more than 48000+ local journeys [2] and they depend on coach operators for most of their national and international journeys [3]. Coach journeys are considered to be one of the safest modes of transport, in comparison with other modes of transport but, it has a higher percentage of casualties per accident [4, 5]. According to national accident statistics of Great Britain (GB), between 2005 and 2015, 1191 children were injured in 371 coach crashes [6]. Contributory factors for these accidents were driver errors and technical faults in vehicles caused by operator non-compliance [7]. Even having strict regulations on operator's compliance with government guidelines, in 2016 alone, 137 coach operators' licenses have been revoked in GB due to operator's noncompliance [8]. This indicates that the existing regulations have not been properly implemented by coach operators. This indicates that there is a need for validation of coach operators, drivers and vehicles before they commence any journey. There are only limited studies

T. Kováčiková et al. (Eds.): INTSYS 2017, LNICST 222, pp. 183–191, 2018.
https://doi.org/10.1007/978-3-319-93710-6_20

available in the literature that analyse the safety of school transport through coaches in the UK. Also, there is no specific safety model available to improve the safety of children travelling by coaches. In this paper, we propose a novel, safety model for validation of UK coach operators. The model has been developed as a response to government accident statistics [6], traffic commissioner reports [8] and a qualitative survey conducted in the UK. The model collects data relating to vehicles, drivers and coach operators and calculates safety scores based on the operator's compliance to the UK government's safety guidelines. These safety scores are then used to rank coach operators from the most to the least safe. The scores will guide schools in their selection of coach operators. The remainder of this paper is organized as follows. An overview of the existing technologies and relevant models are discussed in Sect. 2. The analysis of a qualitative survey is presented in Sect. 3. Significant issues and requirements have been identified which are discussed in the Sect. 4. Section 5 describes the proposed model and Sect. 6 provides discussions on its evaluation. Finally, conclusions and future work are outlined in Sect. 7.

2 Literature Review

Recent fatal accidents involving school children in the UK have alarmed safety professionals and the UK government [9–11]. Reducing coach accidents through policy updates [12] has been one of the most important goals of the UK government for a long time, as it involves a high number of fatalities per accident. This concern is even more important in school transport, which is more critical than other types of transport, as it involves school children, who are the most vulnerable users. Recent advances in school transport systems has given birth to intelligent school transport systems (ISTS) which attempts to tackle issues faced in school transport which may be classified in to three major categories; school bus routing, vehicle & driver monitoring and children monitoring [13]. However, there are limited studies addressing the validation of coach operator compliance [14]. In 2014, revised home to school travel and transport guidance was released by the UK government for local authorities, parents and other interested parties [12]. No criterion for selecting coach operators for school trips was included in the guidance. There are 217 county councils in the UK (England – 152, Scotland – 32, Wales – 22 and Northern Ireland – 11). County councils follow the national transport guidelines for home to school travel. However, some county councils have amended the national guidelines and created an enhanced version [14]. In addition, Northamptonshire county council has compiled a checklist for coach operators, wherein they require the operators to confirm compliance by signing and passing it on to the school's Headmaster before the journey [15]. The checklist helps operators to reiterate whether the coach and driver(s) are fit for purpose. To reduce accidents due to operators' non-safety compliance, and to help the operators to improve their safety levels, the Volvo vehicle manufacturing company has implemented a scientific approach for their coaches and trucks. The system monitors the four main requirements of the Driver and Vehicle Licensing Agency (DVLA) that include road worthiness, traffic enforcement, monitoring and safety [16]. Volvo has also implemented real-time on-board fault diagnostic systems, active truck load monitoring systems and Volvo's

Dynafleet online on some of the products to keep their coaches safe, legal and in control. The system also includes a service point online to keep the data associated with the Driver Vehicle and Standards Agency (DVSA) compliant. However, there is still a knowledge gap with schools in respect of the operators' safety compliance which can be used prior to booking a coach. There is no specific safety model available to guide and ensure the safety of children travelling in coaches in the UK [13]. Therefore, a novel safety transport model which validates the coach operators and guides the schools to select the safest operator while booking the journey is proposed. The development of the model was guided by the analysis of the coach based school accidents records from the STATS19 database [6], the traffic commissioners' reports [8] and a survey which was conducted utilising relevant authorities, practitioners and users.

3 The Survey

A qualitative survey was conducted in Luton Borough Council (in the East of England), which had more coach accidents and operator licenses revoked compared to most of the other regions. The survey was conducted for a period of 6 months, between March 2016 and September 2016. A total of 42 experienced stakeholders (coach operators, coach drivers, parents, school headmasters, road-safety analysts and council transport officers) were selected for in-depth qualitative interviews. The thematic analysis method proposed by Braun and Clark [17, 18] was used to analyse the transcripts. The results showed two major themes, safety issues and requirements of the stakeholders, for coach based school transport as shown in Tables 1 and 2.

Table 1. Top 10 safety issues identified.

No.	Safety issues
1	Unaware of driver and vehicle condition
2	Children behaviour at (bus stop, inside bus)
3	Time delays by parents-drivers (lateness)
4	Inexperienced driver (driver error)
5	Driver got disturbed by pupils in bus
6	Vehicle out of control (vehicle error)
7	Driver fatigue
8	Other vehicles behaviour around the bus (External factors)
9	21 h double team journey
10	Driving hours (real rest time)

Table 2. Top 10 requirements identified.

No.	Requirements
1	Bus escorts
2	Vehicle tracking
3	Information about driver's and vehicle's status
4	Supervise students at the bus stops
5	CCTV cameras
6	Schools need to check the vehicle's and driver's documents for safety reasons
7	Requirement for driver – passenger education
8	Avoid narrow roads and sharp bends
9	Use routes with brighter bus stops
10	Bus drivers prefer motorways

4 Significant Issues and Requirements

In an attempt to reduce accidents for children travelling by coaches, the UK government guidelines [12, 22–32, 33, 34] were considered. The requirement for coach operators to maintain the safety of their fleet in the UK was also used as an important issue for consideration. The following table shows the importance of the issues and requirements over others (Table 3).

Table 3. Significant issues and requirements.

No.	Issues/Requirements	How the proposed model going to solve it?
1	Unaware of driver and vehicle condition	The model will bridge the gap between the stakeholders by presenting the vehicle and driver safety scores to the customers (schools/parents) when they try to book a coach with the coach operator
2	Inexperienced driver (driver error)	Safety score for each driver is calculated based on the driver experience and points on his/her license + other factors (DBS, Health records, Driving hour violations etc.). So the accidents occurring due to driver error [7] can be reduced by selecting the right driver
3	Vehicle out of control (vehicle error)	Safety score for each vehicle is calculated based on various vehicle related attributes which includes, vehicle accident history, daily walk around checks, 6/8/12 weekly safety checks, yearly MOT, valid Insurance etc. Accidents occurring due to vehicle error [7] can be reduced by selecting the right vehicle
4	Driver Fatigue	One of the attributes for calculating the driver safety score is the driver's driving hour violation through the analysis of Tachograph history. Using the driver who has low violation in driving hours may possibly reduce accidents occurring due to driver fatigue [19] caused by irregular rest
5	Information about driver and vehicle status	Similar to Issue No. 1, Parents and Schools requested to check the driver's and vehicle's status before the journey to validate them (i.e.) to make sure they are safe for the journey
6	Schools need to check the vehicle's and the driver's documents for safety reasons	Similar to Issue No. 1. Parents requested the schools to check the driver's and vehicle's documents for a safe journey. Both, point 5 and 6 can be rectified through this model

5 Cloud Based Coach Operator Validator Model

Before the model is discussed in detail, it is important to understand how the quotation process works. For the purpose of this paper, quotation is the process for obtaining prices from coach operators for a particular school journey between two points. Usually a Headmaster or an event coordinator in a school carries out a safety assessment for a school trip and then selects an appropriate coach operator to provide the service. There are many coach operators in the UK who provide coach services for school trips. To select a coach operator, a Headmaster/event coordinator (users) normally provides details of a school journey to several coach operators (brokers) to obtain quotations. A quotation normally provides a list of vehicles with corresponding prices for the journey. The prices vary depending on the type of coach and number of passengers. If the user is happy with the quotation, a booking is made for the coach. Figure 1 shows the existing quotation process where no validation of coach operators involved.

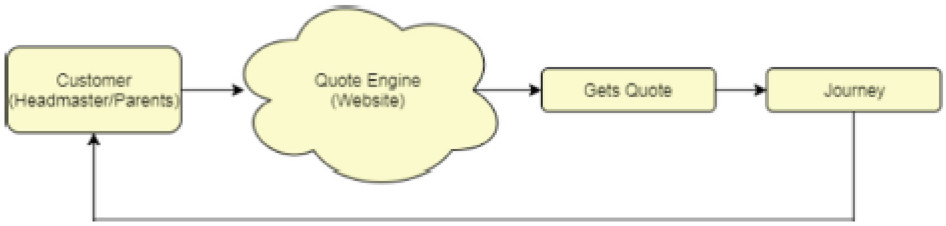


Fig. 1. Existing quotation process.

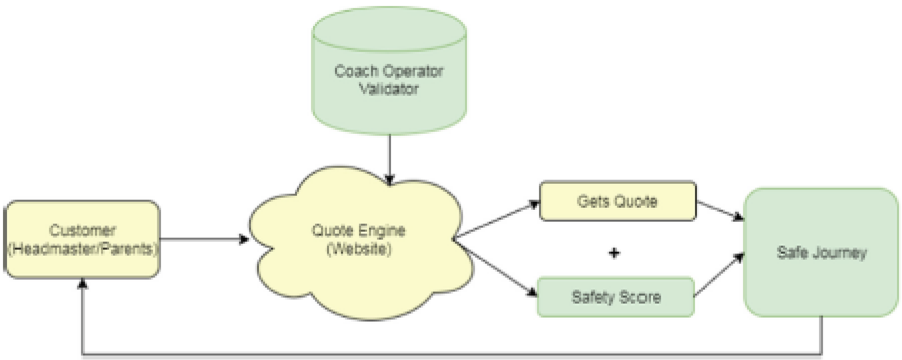


Fig. 2. Proposed quotation process.

We propose a model to introduce a coach journey validator that connects with the existing quotation system as shown in Fig. 2. The model can also act as a stand-alone system for validation of a coach operator without the quotation engine. The proposed model consists of 5 steps: data acquisition, data verification, data weight assignment, safety score calculation and quote engine connection. Basically, the model collects a coach operator's data relating to vehicles and drivers and produces a safety score for each journey. Weighting parameters are used, based on the UK government's guidelines and regulations for coach operators [20–32] to determine the safety level. Figure 3 shows the process decomposition of the model for creation of the journey validator.

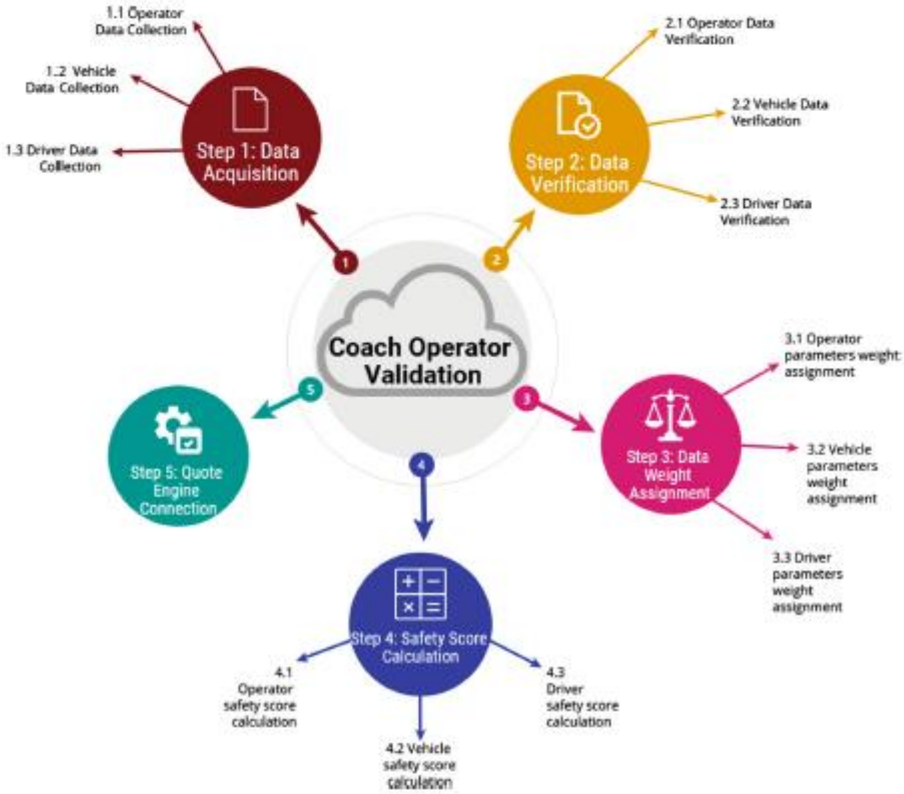


Fig. 3. Coach operator validator model process decomposition.

Data Acquisition: Coach Operator's data in respect of vehicles and drivers are obtained through a data acquisition process. The key step in this model is the data acquisition phase in which, the attributes and parameters are determined according to the standards set by Driver Vehicle and Standards Agency (DVSA), in addition to following the guidelines for coach operators in the UK [22–32, 33, 34]. First, detailed information such as, Traffic Operator Compliance Risk (OCR) scores, Roadworthiness OCR scores, Combined OCR scores, operator license validity etc., are collected. Information about the fleet such as the number of vehicles in the fleet, safety checks, the compulsory tests set by the Ministry of Transport (MOT), insurance validity, vehicle accident history etc., are collected. Data related to drivers working for the operator, including the number of drivers, their experience, points on their licenses, DBS checks, etc. are also collected.

Data Verification: Subsequent to obtaining the data from the operator, it is verified using authorised government databases. First the operator's data is retrieved from the DVSA database and compared with the information obtained from the operator. If they match, then the operator's data is verified. Similarly, vehicles and drivers' data are retrieved from the operator and compared with the information on the DVLA databases for verification.

Data Weight Assignment: Once the coach operator's data is verified, it is divided into three parts: operator's attributes, vehicle's attributes and driver's attributes. Subsequently, weighting factors are assigned to the attributes using the UK Government's scoring systems to calculate the safety scores data. High risk attributes have higher weighting factor whereas the medium and minimal risk attributes are given lower weighting factors. (Example: OCR score attribute can have a weighting factor distribution of 3 to 1 based on the OCR score i.e., Green −3, Amber −2 and Red −1).

Safety Score Calculation: Once the weighting factors are assigned, individual safety scores for an operator, their vehicles and their drivers are calculated. Details of safety score calculations are discussed in [32].

Quote Engine Connection: Once details of a school trip are provided to the quote engine of a coach operator, a list of vehicles along with their safety scores and quotations for each vehicle are displayed. More details be found in [32].

6 Testing the Model

The model was tested in-house and by a number of practitioners. During in-house testing, data was fed into the model to check accuracy of performance. Corrections were made during this initial test and the model was refined further. Real time data was obtained from two coach operators in Luton in the UK who are registered with Luton Borough Council, who also contributed to the testing process and used to test the model. More details may be found in [32]. Feedback received from the coach operators, who were involved during the testing process, was also incorporated within the model.

Results confirmed that the model works well and safety scores calculated for typical journeys were accurate, when compared with scores obtained from authorised UK Government sources. The real-time test has so far confirmed the capability of the model, which may be used for wider applications, possibly globally after some modifications to it.

To further confirm it is fit for purpose and its capability, the model will be evaluated shortly by a larger number of transport companies within the Luton Borough County and across the UK.

7 Conclusion and Future Work

Safety of school transport is a critical issue which should be addressed effectively. Safety in coach-based school transport in GB is a less investigated area compared to other modes of school transport. Coach operator's non-compliance is a major issue in the coach industry. This requires immediate attention before more children lives are put at risk. This paper presents a novel safety transport model for validation of operators/coaches for school journeys in the UK. The results of a qualitative survey conducted for school coach journeys in the UK were presented and significant issues and the requirements were identified and discussed. A model is proposed for validating operators/coaches for school trips prior to their bookings. Testing of the model using real data from two coach operators in Luton confirmed its capability. The model may be deployed for wider applications across the UK to reduce the number of accidents due to operators' non-compliance. By providing safety scores, the model can inform users (schools and parents) of suitable operators, vehicles and drivers for school journeys. The model will be evaluated by the participation of a large number of transport companies within the Luton Borough County and across the UK.

There is potential to expand the model further. Features such as vehicle monitoring and driver monitoring, etc., can be integrated in this model.

References

1. Kalogirou, K., Chalkia, E., Bekiaris, E., Diederichs, F.: An application for the information of children according their school transportation. Procedia Soc. Behav. Sci. **48**, 363–372 (2012)
2. Drake, R.: Schools, pupils and their characteristics. https://www.gov.uk/government/statistics/schools-pupils-and-their-characteristics-january-2016
3. Move, D.G.: Comprehensive Study on Passenger Transport by Coach in Europe (2016)
4. Albertsson, P., Björnstig, U., Falkmer, T.: The Haddon matrix, a tool for investigating severe bus and coach crashes. Int. J. Disaster Med. **1**(2), 109–119 (2003)
5. Doohan, I., Saveman, B.I.: Impact on life after a major bus crash - a qualitative study of survivors' experiences. Scand. J. Caring Sci. **28**, 155–163 (2014)
6. DfT: Department for Transport (Great Britan) Road Safety Data – Datasets. https://data.gov.uk/dataset/road-accidents-safety-data
7. DfT: Department for Transport (Great Britan): Contributory factors for reported road accidents. https://www.gov.uk/government/statistical-data-sets/ras50-contributory-factors
8. Traffic Commissioners: Traffic Commissioners' Annual Reports. https://www.gov.uk/government/collections/traffic-commissioners-annual-reports
9. Bishop, R., Campbell, S.: France coach crash: two British school kids critically injured and 13 hurt in motorway accident (2016). http://www.mirror.co.uk/news/world-news/france-coach-crash-two-british-8477595
10. Fox, A., Bumett, R.: British teen crawled through bus wreckage with a broken back to escape Spain crash that killed 13 students (2016). http://www.mirror.co.uk/news/uk-news/british-teen-crawled-through-bus-7599983
11. Espinoza, J.: Coach driver killed as bus carrying British school children crashes in Belgium (2015). http://www.telegraph.co.uk/news/worldnews/europe/belgium/11704108/One-killed-as-bus-carrying-British-schoolchildren-crashes-in-Belgium.html

12. Department for Education: Home to school travel and transport guidance: Statutory guidance for local authorities, pp. 1–37 (2014)
13. Ramachandran, M., Sahandi, R., Prakoonwit, S., Khan, W.: Intelligent safety transport framework for schools: a review of route planning and tracking systems, p. 7 (2016)
14. Van Ristell, J.A., Quddus, M.A., Enoch, M.P., Wang, C., Hardy, P.: Quantifying the impacts of subsidy policies on home-to-school pupil travel by bus in England. Transportation (Amst). **42**, 45–69 (2014)
15. Northamptonshire County Council: School Transport Policy. http://www.northamptonshire.gov.uk/en/councilservices/EducationandLearning/Parents/travel/Pages/HtoS.aspx
16. Trucks, V.: Operator compliance (2013)
17. Clarke, V., Braun, V.: Teaching thematic analysis: overcoming challenges and developing strategies for effective learning. Psychologist **26**, 120–123 (2013)
18. Braun, V., Clarke, V.: Using thematic analysis in psychology. Thematic. Qual. Res. Psychol. **3**, 77–101 (2006)
19. VOSA: Rules on Drivers' Hours and Tachographs: Passenger-carrying vehicles in GB and Europe (2011)
20. VOSA: Public Service Vehicle Operator Licensing Guide for Operators (2011)
21. DVSA: Staying legal: PSV driver basics (2014)
22. IRTE: Wheel Security (2015)
23. Health and Safety Executive: Driving at work (2014)
24. Health and Safety Executive: Risk Assessment - A brief guide to controlling risk in the workplace (2014)
25. Health and Safety Executive: Reporting accidents and incidents at work A brief guide to the Reporting of Injuries, Diseases and Dangerous Occurrences Regulations 2013 (RIDDOR) (2013)
26. Health and Safety Executive: Decide who will help you with your duties (2013)
27. DVSA: National standard for driving buses and coaches (2013)
28. DVSA: Guide to maintaining roadworthiness, p. 54 (2014)
29. DVSA: The safe operator's guide (2016)
30. IRTE: Roadworthiness: Industry Best Practice for PCV (Passenger Carrying Vehicles) (2008)
31. DVSA: Careless Torque Costs Lives (2014)
32. Ramachandran, M., Sahandi, R., Prakoonwit, S., Khan, W.: Mathematical model for safety score calculation for validation of coach operators in the UK. In: Intelligent Transport Systems – From Research and Development to the Market Uptake. Springer, Heidelberg (2017)

Mathematical Model for Safety Score Calculation for Validation of Coach Operators in the UK

Manoharan Ramachandran(✉), Reza Sahandi, Simant Prakoonwit, and Wajid Khan

Faculty of Science and Technology, Bournemouth University, Bournemouth, UK
{mramchandran, rsahandi, sprakoonwit, wkhan}@bournemouth.ac.uk

Abstract. Coaches are considered the safest mode of road transport for school trips. In the last decade alone, 1191 children were injured in 371 coach crashes in the UK. Consequently, the UK government enforced strict regulations on coach operators to reduce accidents. During 2016, 137 coach operator licenses have been revoked due to operator non-compliance. To increase safety of children travelling by coaches, we previously proposed a safety transport model for validation of coach operators. In this paper, a mathematical model for calculation of safety scores is presented. Real data from two transport organisations was used to test the model. Results show that, the proposed mathematical model works very well, as illustrated in this paper.

Keywords: Safety score calculation · Coach operator validation School journeys · Coach transport

1 Introduction

Coaches are considered as the safest mode of school transport for children [1]. Every year, in England alone more than 48000 school trips are made [2] and for most of the trips, schools rely on coach operators [3]. Analysis of the national accidents data in the UK revealed that, in the last 10 years, 1191 children have been injured in 371 coach crashes [4]. Driver errors and faults in the vehicles due to operators' non-compliance were reported as the major contributory factors for these coach crashes [5]. To reduce coach accidents, the UK government has created strict regulations to be applied by coach operators [6]. The UK government has also developed a coach Operator Compliance Risk Score (OCRS) system [7]. The system calculates the compliance risk scores for all the operators in the UK based on their fleet and drivers performance in last three years. If during an inspection a vehicle or a driver is found to be non-compliance to the safety rules, the operator will be referred for a public enquiry. An operator may lose its license if found guilty in a public enquiry. But OCRS only applies to the operators and not for their individual vehicles or drivers. Increasingly a number of operators are losing their licenses every year. In 2016 alone, 137 coach operators' licenses have been revoked in the UK, due to their non-compliance [8]. Accidents are

T. Kováčiková et al. (Eds.): INTSYS 2017, LNICST 222, pp. 174–182, 2018.
https://doi.org/10.1007/978-3-319-93710-6_19

still happening despite having strict regulations. This raises the question whether school transport through coaches in the UK is really safe? In a survey conducted in the Luton Borough Council in the UK, it was found that coaches are booked for trips based on trust of Coach Operators and schools rarely check the operators for their compliance with the safety regulations [9]. A safety transport model for schools which provides safety scores for validation of coach operators in the UK has been developed [10]. This will enable schools to check safety scores of coach operators, their vehicles and drivers before booking coaches for the journeys. This paper provides details of a mathematical model for calculation of safety scores, which are used in the model. The remainder of this paper is organized as follows. A short description of our safety model is provided in Sect. 2. The mathematical model is presented in Sect. 3, followed by safety scores calculation in Sect. 4 and testing the model in Sect. 5. Finally, conclusions and future works are outlined in Sect. 6.

2 Coach Operator Validation Model

The proposed model consists of 5 steps as shown in Fig. 1. In step 1, coach operator's data which includes vehicle data (such as, safety checks, MOT, insurance, etc.) and driver's data (such as, points on the license and its expiry date, DBS checks, experience etc.) along with Operator Compliance Risk (OCR) score are obtained. In step 2, the data is verified through a comparison process with an authorized database. Step 3 assigns weights to the data parameters based on the UK government's scoring system [7]. In step 4 safety scores are calculated. Finally, in step 5, the safety scores are presented along with the prices obtained from a quote engine. This paper focuses on the steps 3 and 4 of the process which gives a brief description of the validation process of coach operators. This also includes detailed discussions on the calculation of safety scores step 4 in the validation process.

Fig. 1. Cloud based coach journey validator model.

3 Mathematical Model

Figure 2 illustrates the process and assignment of weights for the calculation of the safety scores. The calculation starts from the assignment of weight (w) to each parameter.

Coach operator's data comprises of attributes (a_n) and parameters (p_m) where n denotes the total number of attributes and m denotes the total number of parameters for the attributes (Eg. OCRS is an operator's attribute: green, amber, red and grey are the OCRS parameters). An attribute (a_1) may have more than one parameters ranging from p_1, p_2, …, p_b and p_m where p_b denotes the not applicable parameter which is

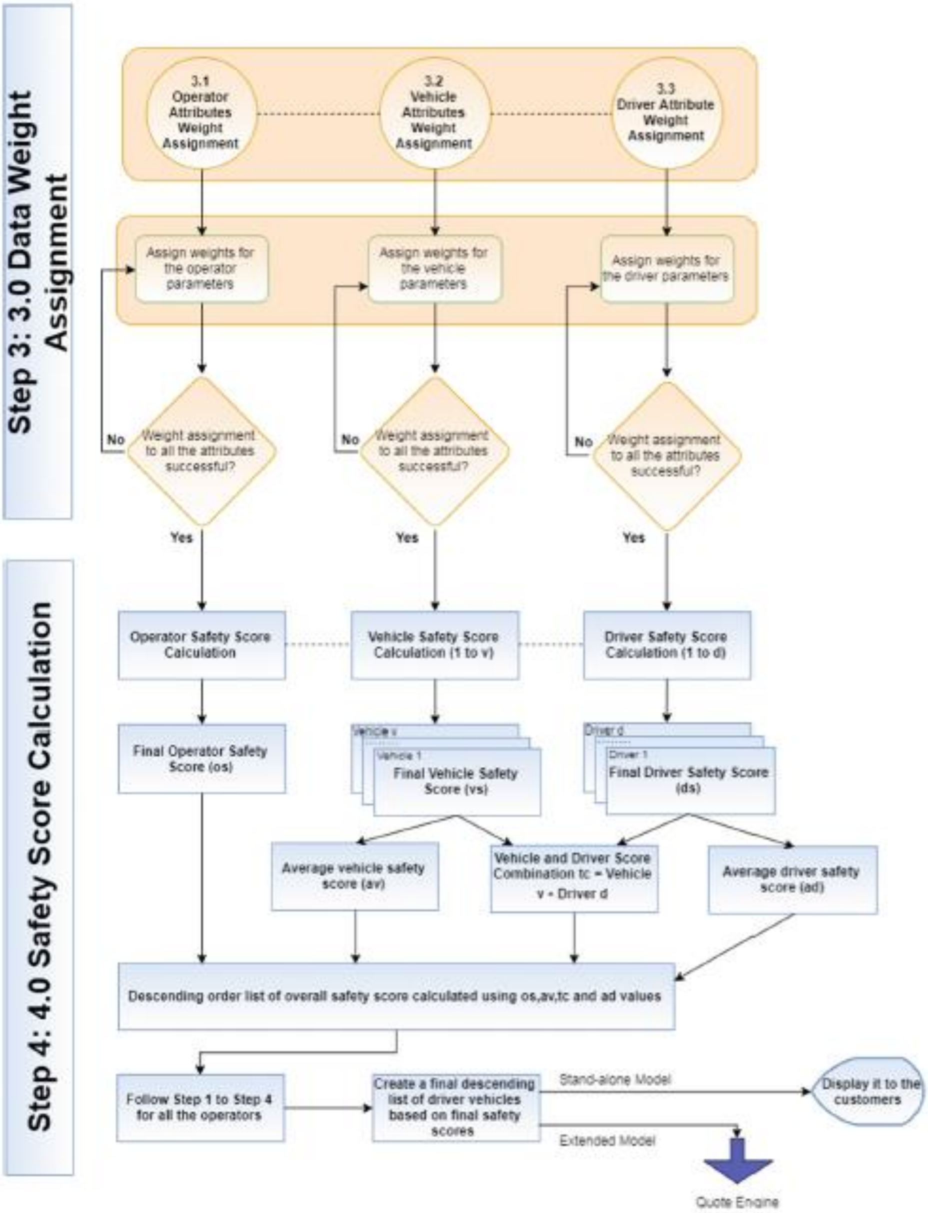


Fig. 2. Data weight assignment and safety score calculation.

necessary to exclude the attributes which are not applicable to an operator at a particular time.

Weights for the parameters for the operator, their vehicles and drivers are then assigned. The weights are assigned based on the UK government's scoring system [7]. In this respect x_i denotes the total weight for non-applicable attributes, y_i the total weight possible when all the attributes have maximum weights and z_i the overall weight obtained for all the attributes. The following calculations are based on one operator, its vehicles and drivers. The same formulae can be used to calculate the safety scores of all the operators which are explained in Sect. 4. The individual safety scores for the operator (os), its vehicles (vs) and drivers (ds) are then calculated.

Equation (1) shows the calculation of the overall safety score for an operator, where n denotes the total number of operator attributes, z_i the total weight obtained by all the attributes, y_i denotes the total weight possible when all the attributes maximum weights and x_i denotes the total weight for non-applicable attributes.

$$os = \left(\frac{\sum_{i=1}^{n} z_i}{\sum_{i=1}^{n} y_i - \sum_{i=1}^{n} x_i} \right) \times 100 \quad (1)$$

Equation (2) shows the calculation of vehicle's safety score, where n denotes the total number of vehicle attributes. Other parameters are similar to Eq. (1),

$$vs = \left(\frac{\sum_{i=1}^{n} z_i}{\sum_{i=1}^{n} y_i - \sum_{i=1}^{n} x_i} \right) \times 100 \quad (2)$$

Equation (3) shows the calculation of driver's safety score, where n denotes the total number of driver attributes. Other parameters are similar to Eq. (1),

$$ds = \left(\frac{\sum_{i=1}^{n} z_i}{\sum_{i=1}^{n} y_i - \sum_{i=1}^{n} x_i} \right) \times 100 \quad (3)$$

All the safety scores (os, vs and ds) are expressed out of 100 (percentage). One operator may have more than one vehicle and a driver. In Eq. (4), av is the average safety scores for all the vehicles and u denotes the total number of vehicles belongs to an operator and vs_i the safety score for vehicle i respectively.

$$av = \left(\frac{1}{u} \right) \times \sum_{i=1}^{u} vs_i \quad (4)$$

In Eq. (5), ad is the average safety scores for the drivers of an operator, e denotes the total number of drivers belongs to the operator, ds_i denotes the safety score for driver i.

$$ad = \left(\frac{1}{e} \right) \times \sum_{i=1}^{e} ds_i \quad (5)$$

Average scores for a vehicle and driver(s) are useful information for recommendation of operators to a customer, as well denoting the safety level of the entire fleet.

4 Safety Score Calculation for a Journey

To calculate the safety score for a journey, safety score combinations of available vehicles and drivers in a fleet are used. To find the best possible driver & vehicle combinations the steps below are followed;

Step 1: The number of possible vehicle and driver combination (c) are calculated using Eq. (6). In this equation, u and e denote the total number of vehicles and drivers respectively.

$$c = u * e \tag{6}$$

Step 2: To find the sample space Ω between the vehicle's safety scores and driver's safety scores, Eq. (7) is used. In this equation, vs and ds denote vehicle and driver safety scores respectively.

$$Sample\ Space, \Omega = \{(vs_1, ds_1), (vs_2, ds_2), \ldots (vs_u, ds_e)\} \tag{7}$$

Step 3: To find the sum for all the combinations, Eq. (8) is used. To find the average for individual combinations of q, Eq. (9) is used.

$$q = Individual\ Sum\{\Omega\} \tag{8}$$

$$q = \{vd_1, vd_2, \ldots\ldots\ldots, vd_c\}$$

Where, $vd_1 = vs_1 + ds_1$, $vd_2 = vs_1 + ds_2$, ... $vd_c = vs_u + ds_e$ ($vs_u + ds_e$ denotes the last possible driver and vehicle combination)

$$avg = q * \left(\frac{1}{2}\right) \tag{9}$$

Step 4: To arrange the combinations in descending order, Eq. (10) is used.

$$l[i] = sortdesc(avg) \tag{10}$$

l is the list of vehicle-driver combination averages in descending order and i represents the individual values inside the l where, i = 1 to c.

$$fl[i] = (os * \mu)/100 + (av * \alpha)/100 + (ad * \beta)/100 + (l[i] * \rho)/100 \tag{11}$$

Equation (11) shows the final safety score list ($fl[i]$) for one operator. To give weightage for the values of os, av, ad and $l[i]$, constants (μ, α, β, ρ) are used. By using these constants, weights for individual variables can be specified (ex. μ = 10, α = 5, β = 5, ρ = 80). Using the Eq. (12), list of possible driver and vehicle combinations under an operator who is registered with the coach broker can be calculated. The final list of operators and their safety scores will be listed as,

$$js = sortdesc(fl_1[i], fl_2[i], fl_3[i]\ldots, fl_\sigma[i]) \tag{12}$$

Where, σ denotes the total number of operators registered with a coach broker, i denotes the number of vehicle and driver combinations for each operator which ranges from 1 to c and js denotes the Journey Score list. The total number of combinational values inside the js can be calculated by adding c values of all the operators (i.e.) js $[c_1 + c_2 + \cdots + c_\sigma]$, where σ denotes the total number of operators registered with the coach broker.

5 Testing

The proposed equations were tested for appropriateness and accuracy using real data from two coach operators in Luton in the UK who are registered with the Luton Borough Council. For confidentiality, the names of the operators are anonymised as Operator A and B. Operator A had 3 coaches and 4 drivers. Operator B had 2 coaches and 3 drivers. Following the information from previous section weights for the operator and the parameters for its vehicles and drivers were assigned and using the Eqs. (1) and (2) the values were calculated and recorded. To obtain the scores for A:

Overall safety score - Eq. (1),

$$os = \left(\frac{8}{11-1}\right) \times 100 \; = > \; os = 80\%$$

Individual vehicle safety score - Eq. (2),

$$vs_1 = \left(\frac{8}{12-2}\right) \times 100 \; = > \; vs_1 = 80\%$$

Repeating the above equation and by applying the operator parameters for all the vehicles, following values are obtained; vs_2 = 81.81% vs_3 = 81.81%.

Average vehicle safety score - Eq. (4),

$$av = \left(\frac{1}{3}\right) \times (80 + 81.8 + 81.81) \; = > \; av = 81.21\%$$

Similarly to calculate the driver safety scores:

Individual driver safety score - Eq. (3),

$$ds_1 = \left(\frac{7}{10-0}\right) \times 100 \; = > \; ds_1 = 70\%$$

Repeating the above equation for all the 4 drivers, ds_2 = 55.55%; ds_3 = 90.00% and ds_4 = 60.00%.

Average driver safety score - Eq. (5),

$$ad = \left(\frac{1}{4}\right) \times (70 + 55.55 + 90 + 60) \; = > \; ad = 68.88\%$$

Tables 1 and 2 show the safety scores of the Operator A for their individual coaches and drivers.

Table 1. Vehicle safety score values.

Vehicle no.	vs_v	Score
1	vs_1	80.00%
2	vs_2	81.81%
3	vs_3	81.81%
u = 3		av = 81.21%

Table 2. Driver safety score values.

Driver no.	ds_d	Score
1	ds_1	70.00%
2	ds_2	55.55%
3	ds_3	90.00%
4	ds_4	60.00%
e = 4		ad = 68.00%

To find the best possible driver & vehicle combinations following steps are followed,

step 1: The total numbers of possible combinations, using Eq. (6): c = 12. This means, there are 12 possible driver-vehicle combinations in total.

step 2: The sample space, using Eq. (7),

$$\text{Sample Space, } \Omega = \{(80, 70), (80, 55.55), \ldots, (81.81, 60)\}.$$

step 3: The sum for all the combinations using Eq. (8),

$$q = \{(80 + 70), (80 + 55.55), \ldots, (81.81 + 60)\}.$$

Using Eq. (9)

$$avg = \{150, 135.55, \ldots, 141.81\} * (1/2) \; = > \; avg = \{75, 67.77, \ldots, 70.90\}$$

step 4: The combinations in descending order using Eq. (10):

$$l[i] = \text{sort-desc}(\{75, 67.77, 85, 70, 75.90, 68.68, 85.90, 70.905, 75.905, 68.68, 85.90, 70.90)\}$$

$$l[i] = \{85.90, 85.90, 85, 75.90, 75.90, 75, 70.90, 70.90, 70, 68.68, 68.68, 67.775\}$$

For the final safety score list using Eq. (11): The constant values used are: μ = 10, α = 5, β = 5, ρ = 80 and i = 1 to 12.

$$fl[1] = (80 * 10)/100 + (81.21 * 5)/100 + (68 * 5)/100 + (85.90 * 80)/100$$

$$fl[1] = 84.18\%$$

Where, $\mu = 10$, $\alpha = 5$, $\beta = 5$, $\rho = 80$ and $i = 1$ to 12. $fl_1[i]$ = Final safety score combination list for 1 operator. $fl_1[i] = \{84.18, 84.18, 83.46, 76.18, 76.18, 75.46, 72.18, 72.18, 71.46, 70.40, 70.40, 69.68\}$. Table 3 shows the mapping of average values and sums for the vehicle and driver combinations (i.e. complete list of all the final values for Operator A).

Table 3. Mapping of average values with vehicle and driver combinations for Operator A.

l[i]	vs_v	ds_d	Sum	Average	$fl[i]$
l[1]	vs_2	ds_3	171.81	85.90	84.18%
l[2]	vs_3	ds_3	171.81	85.90	84.18%
l[3]	vs_1	ds_3	170	85	83.46%
l[4]	vs_2	ds_1	151.81	75.90	76.18%
l[5]	vs_3	ds_1	151.81	75.90	76.18%
l[6]	vs_1	ds_1	150	75	75.46%
l[7]	vs_2	ds_4	141.81	70.90	72.18%
l[8]	vs_3	ds_4	141.81	70.90	72.18%
l[9]	vs_1	ds_4	140	70	71.46%
l[10]	vs_2	ds_2	137.36	68.68	70.40%
l[11]	vs_3	ds_2	137.36	68.68	70.40%
l[12]	vs_1	ds_2	135.55	67.77	69.68%

The same approach is used to calculate the safety scores for Operator B. Table 4 shows the Mapping of average values with vehicle and driver combinations for Operator B.

Table 4. Mapping of average values, sums for vehicle and driver combinations for Operator B.

l[i]	vs_v	ds_d	Sum	Average	$fl[i]$
l[1]	vs_2	ds_3	171.88	85.94	84.22%
l[2]	vs_2	ds_2	165.60	82.80	81.75%
l[3]	vs_1	ds_3	151.64	75.82	76.12%
l[4]	vs_2	ds_1	137.20	68.60	70.33%
l[5]	vs_1	ds_1	135.76	67.88	69.88%
l[6]	vs_1	ds_2	133.48	66.74	68.75%

Equation (12) can then be used to sort in descending order, the final list of vehicle/driver combinations for both the operators.

$$\text{jsl}\ [c_{\sigma=1to2}] = (84.22, 84.18, 84.18, 83.46, 81.75, 76.18, 76.18, 76.12, 75.46, 72.18, 72.18, 71.46, 70.40, 70.40, 70.33, 69.88, 69.68, 68.74)$$

6 Conclusion and Future Work

Safety of school transportation is a critical issue which should be addressed effectively. Safety in coach-based school transport in the UK is a less investigated area, compared to the other modes of transport for schools. Operator non-compliance is a major issue in the coach industry. This requires an urgent attention before more children lives are put at risk. This paper presented a mathematical model for calculation of safety scores for coach operators which is a part of a proposed safety transport model. This paper by applying real data from two coach operators illustrated that the mathematical model works well. As our future work, the model will be further validated by making it available to wider groups of practitioners/users for comments. The results will also be subsequently published.

References

1. O'neal, E., Ramirez, M., Cara, H., Tracy, Y., Stahlhut, M., Peek-Asa, C.: School bus crash rates on routine and nonroutine routes. J. Sch. Health. **84**, 575–580 (2014)
2. Drake, R.: Schools, pupils and their characteristics. https://www.gov.uk/government/statistics/schools-pupils-and-their-characteristics-january-2016
3. Move, D.G.: Comprehensive study on passenger transport by coach in Europe (2016)
4. DfT: Department for Transport (Great Britain) Road Safety Data – Datasets. https://data.gov.uk/dataset/road-accidents-safety-data
5. DfT: Department for Transport (Great Britan): Contributory factors for reported road accidents. https://www.gov.uk/government/statistical-data-sets/ras50-contributory-factors
6. Department for Education: Home to school travel and transport guidance: statutory guidance for local authorities. 1–37 (2014)
7. DVSA: Use the Operator Compliance Risk Score (OCRS) system
8. Commissioners, T.: Traffic Commissioners' Annual Reports. https://www.gov.uk/government/collections/traffic-commissioners-annual-reports
9. Ramachandran, M., Sahandi, R., Prakoonwit, S., Khan, W.: Intelligent safety transport framework for schools: a review of route planning and tracking systems. 7 (2016)
10. Ramachandran, M., Sahandi, R., Prakoonwit, S., Khan, W., Mohd Selamat, S.A.: A safety transport model for validation of UK coach operators for school journeys. In: Intelligent Transport Systems – From Research and Development to the Market Uptake. Springer (2017)