UNIVERSITY OF TWENTE.

Safety Analysis of BSO Bus

Safety by Design (201700042)

Student:
Egas Guimarães Marçal - s2646145

Supervisor:
dr. M. Rejabali Nejad

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1. Introduction

The old Stint vehicle was developed to be used by childcare employees to transport children to and from school and extracurricular activities. Stintum, the company responsible for such vehicles, thought it could be a safe, efficient and environmentally friendly way to bring children from one place to another. Initially, the Stint vehicles gained a lot of attention for positive reasons, even receiving approval from governmental entities in 2012 [3]. By 2018, approximately 3000 Stints drove around in the Netherlands. The service, repair and maintenance of these vehicles was performed by Stintum [1].

However, on September 20, 2018 a tragic accident occurred, when a Stint vehicle collided with a train on a railway crossing at Oss, Noord-Brabant, Netherlands. Four children were killed, with two further serious injuries, one child and one adult [2]. The driver of the Stint, a 32-year-old childminder, was unable to stop the vehicle on time, due to an unresponsive braking system [4]. Although the driver was not blamed for the accident, the preliminary findings of a still ongoing inquiry ordered by the Dutch government highlighted reasons for doubt over the technical construction of the Stint [3].

On October 1, 2020, the Dutch Minister for Infrastructure and Water Management, Cora van Nieuwenhuizen, banned Stint vehicles from public roads in the country. On October 29, 2020, Stintum filed for bankruptcy [2]. This decision directly affected 20,000 children [3].

After the accident, the creator of the Stint, Edwin Renzen, created a new vehicle, very similar to the old version, called BSO Bus [5]. In comparison to the original Stints, technical improvements have been made. The first BSO Buses are expected to be broadly delivered in the spring of 2021 [6]. Some childcare center, however, have already received authorization to use these vehicles from December 2020 onwards [16].

After the Stint was discredited, hundreds of childcare organizations invested in the BSO Bus, also called the new Stint. According to the director of the Childcare Sector Organization, one of the alternatives to transport children, the taxi vans, is not safe [5]. The BSO Bus also contributes for a safe traffic situation around schools.

This report is aimed at figuring out whether the BSO Bus is actually safer than the old Stint. The updated safety measures of this vehicle will be investigated, and the current hazards and hazardous situations will be analyzed. This theme was found to be pertinent, due to the high number of children in need of a proper mean of transportation during the day across the Netherlands. In addition, knowing the renewable energies have been playing a very important role lately, it was considered important to focus on an electric urban vehicle.

2. System of Interest (SoI)

The correct definition of the System of Interest (SoI), also called System Under Consideration (SUC) is very important to ensure a flawless safety analysis. The scope of the SUC will now be defined, by describing the system and what physical parts it consists of. The people that have interest in this system and the environment that influences it will also be mentioned.

The Safety Cube Theory will be used to illustrate and discuss the interaction between humans, technical system and environment.

2.1 BSO Buses

The company responsible for the Stints between 2012 and 2018, Stintum, is currently the only one with governmental permission to produce and develop the BSO Buses. The mass commercialization is expected to begin in the spring of 2021 [6].
According to [9], for 2021 there will be six different colors available for the same model of BSO Bus.

2.1.1 Technical System

The BSO Bus is a four-wheel electrical vehicle with a stainless-steel frame. According to [8], each BSO Bus of the Stintum company has a length of 238cm, a height of 177cm, a width of 112cm and a turning cycle capacity of 570cm. The driver, who must have followed a driving skills training [5], stands on a platform and can maneuver the vehicle by a steering column which is directly placed above the platform. The steering column is fixed to the frame of the vehicle, but turns horizontally, allowing steering. This vehicle has a driver detection system with the aim that the vehicle cannot drive without a driver [9].

Conversely to the Stint, the BSO Bus is equipped with a driver's support. When driving, the driver can lean with the inside of the thighs against the driver's support for more stability when cornering [8]. This new feature, as well as the standing platform and the steering wheel are shown in Figure 1.

Figure 1 – Driver's support of the BSO Bus [8].

Figure 2 – Double tilt protection [8].

One of the common features with the Stint vehicles is the existence of a considerably big tub in front of the driver. The maximum capacity of such space is ten seated children, five on each side of the tub. Each seat has seatbelts (Figure 3) and a maximum weight capacity of 45Kg [8]. When the children are seated, the driver has a clear view of what is ahead and does not have his view disrupted.

As an update in comparison to the Stint, the BSO Bus possesses a double tilt protection, placed in the tub. The first protective bar is located close to the driver together with a couple rearview mirrors, to help the driving and allow the driver to visualize other vehicles and obstacles located behind the BSO Bus. The second bar is located in the rear end of the vehicle. This equipment foresees the risk of rollover and prevents its occupants from becoming trapped [8]. We can visualize this new feature in Figure 2.

Figure 3 – Individual seatbelts [9].

All the BSO Buses are equipped with front and rear lighting, flashing light and direction indicators (Figures 4 and 5). The BSO Bus also has a horn [9].

This vehicle is also equipped with a small on-board computer in which information such as the temperature, GPS location, velocity, battery capacity and number of kilometers are displayed (Figure 6).

In Figure 6, represented by the letter E is the parking brake that is easy to operate via the lever on the steering column. This hand brake prevents the vehicle from rolling away [10].

Figures 4 and 5 – Front lights, rear lights and direction indicators [9].

Represented by the letter D on Figure 6 is the emergency button. When pressed, the energy supply to the electric motor is stopped and the velocity of the vehicle is decreased. Other components such as lights and the horn continue working [9]. This way, the vehicle brakes in a controlled manner.

The Stintum BSO Buses are also equipped with two independently operating braking systems. Mechanical drum brakes on the rear axle and hydraulic disc brakes on the front axle [10].

Figure 6 – Small on-board computer, hand brake and emergency button [9].

The electrical vehicle has a direct-current motor with a nominal power of 1200W and has a battery with 24V working power. This results in a maximum speed of 17.2 km/h and a maximum range of 25 km [10]. The motor activates the rear wheels by a fixed transfer ration and a differential. The electrical components are places beneath the driver's platform.

2.1.2 Human

The humans associated directly or indirectly with the BSO Bus are the stakeholders which in this case are:

- Drivers, who normally are daycare employees. Their function is to transport children in a fast and safe way. They want a vehicle that is easy manageable and learnable, that does not cause any accidents in any way.
- Daycare management. Their function is to oversee the work done by the employees in handling the BSO Bus. They intend to transport many children in a fast, safe and cheap way. The managers do not want accidents involving their professionals, because it can damage their reputation.
- Owners of the vehicle, that can be either a singular or a collective entity, such as the childcare company itself
- Users, who normally are daycare children. Their function is to sit comfortably while being transported.

- Parents/caretakers of the daycare. These are the over age people legally responsible for the children.
- Stintum company, which is the current single manufacturer of BSO Buses. They do not want accidents because they want their reputation unharmed.
- Dealers, who are the official retail shops that commercialize parts of the vehicles or entire BSO Buses.
- Auto repair shops, that are places where the vehicles undergo maintenance procedures.
- The executive and legislative power (e.g., road traffic authority, Dutch government, EU).
    - The road authority is a part of the ministry of transport in the Netherlands, which is responsible for regulating and overseeing transport. The Dutch government and EU are the ones making the law and regulations for vehicles such as BSO Buses.
- Hospital stuff, who are the ones taking care of injured users of the BSO Buses in accidents possibly involving other road users such as cyclists, pedestrians and cars.
- Other road users, who are people that directly interact with the BSO Buses and their passengers, such as pedestrians and other drivers.
- Insurance companies, who provide a legal and valid civil responsibility insurance for the owners of the vehicles.

2.1.3 Environment

The environment of the technical system includes aspects such as the physical environment (weather conditions, obstacles on the road/path, roads, signs, condition of the bicycle path, traffic lights), regulations (traffic rules, rules of using the BSO Bus, policies) and collaborating/competing systems, such as other road users and vehicles.

2.2 Safety Cube Theory

The Safety Cube Theory stipulates six fundamental aspects of safety: the human, the technical system, the environment of the technical system, the interaction of human with the technical system, the interaction of the technical system with the environment and the interaction of the human with the environment. These elements can be presented in a matrix form, as shown in Table 1.

The diagonals of this table specify the human, the technical system and the environment of the technical system. The off-diagonal cells of this matrix provide information about the interactions between the diagonals. The off diagonals should be read clockwise in such a way that the associated row offers input for the associated column.

For example, the human-technical system cell in the top row describes individual output as input for the technical system. In contrast, the technical system-human cell in the second row represents the technical system output as input for the human.

	Human	Technical System	Environment
Human	BSO Bus drivers, Daycare management, Owners, Users, Parents/caretakers, Stintum, Dealers, Executive and legislative power, Hospital stuff, Other road users, Insurance companies, Auto repair shops	Human steering, driving behavior, quality control	Driving culture, mutual respect for traffic of other vehicles,
Technical System	Fast, safe and enjoyable transport	BSO Bus	Clear visibility, usage of sensing equipment, lights, direction indicators, horn
Environment	Traffic regulations, driving signals	Condition of the road, weather conditions, traffic regulations, obstacles on the road	Road signs, bicycle paths, traffic lights, weather conditions, other road-vehicles

Table 1 – Safety Cube.

2.3 Design Structure Matrix (DSM)

From the Safety Cube, it is possible to elaborate both of the system elements and their interaction further by the Design Structure Matrix (DSM). The Humans and Environment are used in the DSM as discussed in the Safety Cube. The technical system was divided in some subsystems: steering wheel, braking system, accumulator, electric motor, lighting, wheels, frame and tub and controls. This subdivision would give a better view at how the different subsystems of the BSO Bus are interacting with each other. The six matrices containing the DSM are show in Appendix A.

By discussing the most important interactions, some conclusions can be made. In Human/Human interaction, it can be said that both the parents of the children and the driver of the BSO Bus are the most important stakeholders for the analysis of the present system. While the parents have the legal responsibility for the children and to let them ride in the BSO Bus, the drivers have the actual responsibility to transport the users from one point to another safely and without incidents. In a nutshell, these two stakeholders possess highly important responsibilities that can jeopardize the safety of the children.

Regarding the technical system, it is clear that all the subsystems are major parts of the System Under Consideration. These parts are responsible for a proper functioning of the vehicle if simultaneously in working conditions. Small components such as the horn, protective bars, odometer, speedometer were not considered as subsystems.

Interactions between subsystems of the environment focused mainly on safety of the road. The subsystem weather is a major one, because different weather conditions result in distinct road conditions and therefore different driving conditions.

The interactions between the technical system, the humans and the environment are also explained in Appendix A. For the Human-Environment interaction safety is once again deemed as extremely important. This is achieved by complying with laws and policies and by adjusting to weather conditions, to avoid unpleasant situations, incidents or even fatal accidents.

The Technical system–Human interaction reinforces the fact that all the subsystems are extremely relevant to ensure the main purpose of the BSO Bus, which is the safe transportation of children. This table also depicts the relevance of having competent maintenance shops that assist the owners and perform routine operations in the buses. It can also be seen that the driver of the vehicle has to perform all sorts of operations commonly seen in normal road vehicles to successfully complete the transportation.

The Technical System-Environment interaction essentially shows the needs of the vehicle to adapt to several different weather conditions and still perform properly and comply with the rules. Furthermore, it can be seen that its parts should be reliable and capable of withstand constant vibrations, oscillations and impact of water and other elements.

3. Safety Objectives

This chapter will contain information regarding the safety critical functions of the BSO Bus which are directly connected to the subsystems mentioned in the Section 2.3. The level of safety for each one of the subsystems is identified and, in the end, the required regulations and safety requirements of the BSO Buses are analyzed.

3.1 Safety critical functions and level of safety

Defining the desired level of safety in a given complete system, as the BSO Bus, is quite a complex task. Theoretically, the level of safety for this System of Interest would be the highest possible or maybe even completely free of risks and accidents. Obviously, in practical situations, this is not realistic, as there is always a component of risk present.

For this system, it is safe to say that the desired level of safety is to reduce the number of hazards with high frequency and high severity at the most.

To perform the most detailed analysis possible, the real level of safety was performed having into account the multiple subsystems of the BSO Bus.

For each one of the previously mentioned subsystems of the BSO Bus there is a safety critical function associated, that can vary according to the characteristics of the subsystem, its functionality and purpose. In addition, for each subsystem there is a level of safety that is assigned, mainly according to the inherent risks and hazardous situations. The various levels of safety and further explained in Table 2.

Level of Safety	Description
1	Must be avoided in all circumstances
2	Changes in design must be implemented
3	Technical measures can be taken
4	Information must be provided
5	Risks can be accepted due to low severity

Table 2 – Explanation of Levels of Safety.

In a nutshell, when a level of safety is small, the risks associated to a given subsystem can easily result in serious injuries, permanent disability, death, huge monetary loss and serious impact on the environment.

It is now possible to specify what the safety critical functions for each subsystem are, which is shown in Table 3.

Subsystem	Safety critical function	Level of Safety
Steering Wheel	The steering wheel of the BSO Bus is considered to be one of the most essential physical parts to ensure a good performance of its function. Risks here must have to be eliminated in the design phase, since changing it later can cause delays in production, delivery, etc.	**2**
Braking System	The multiple braking systems of the BSO Bus are included in passenger safety features and any compromise in this subsystem can result in serious injuries or even death of the users. So, it must be tried to remove any chances of risks here.	**1**
Accumulator	The accumulator, which provides energy to the on-board computer and the lights, is included in the power supply features. Errors and malfunctions here are not fatal and can be corrected by a correct replacement and technical procedure.	**3**
Electric Motor	The electric motor of the Bus is included in an energy security feature. This subsystem provides the Bus with electricity. Any issues here could lead to a sudden halt or extremely fast movement. If there is an issue with the electric motor, the human life is put in jeopardy.	**1**
Lighting	The multiple lights of the BSO Bus can be included in trackside control and signaling, which basically refers to the ability of the driver to adapt the vehicle features to the road/weather conditions. Also, the ability to signal to other users and to warn them of changes of direction. Errors here, either human or technical, can turn out to be fatal.	**1**
Wheels	The wheels perform the primary function of protecting the children during transportation. Risks here must be eliminated in the design phase since changing it later can cause delays in production, delivery and other related issues	**2**
Frame and tub	The frame and specially the tub can be seen as comfort features. This is important for children's satisfaction, given that the risks due to sudden breaks are not dangerous when children are seated and with their seat belts on. However, it Is a risk if they are standing, so it is an accepted risk which is solved by giving proper safety information to the children	**4**
Controls	The controls present in the BSO Bus can be considered as communicational and route control features. These are aspects that relate with the driver being able to understand and correctly interpret the signals coming. Therefore, errors here are not fatal. These faults can be tackled by taking technical measures to take care of cases when electronic systems fail.	**3**

Table 3 – Subsystems and respective safety critical function and level of safety.

3.2 Regulations and standards that must be addressed

In this section, national and international regulations that are directly applied to the BSO Bus are going to be further explained. Naturally, the focus is on the Dutch market for BSO Buses, rules and standards that influence this particular product and respective market.

To start with, regulations are rules normally required by the European Commission or a national government, meant to carry out specific legislation that ensure a minimum threshold of safety. Such regulations are usually enforced by a regulatory agency.

In mid 2021, once the BSO Bus is officially released for circulation, the Dutch entity responsible for ensuring the safety of these vehicles is Veilig Verkeer Nederland (VVN).

3.2.1 CE marking

In order to protect the consumer from dangerous products in the European Economic Area, an agreement was made, in which is mentioned that before a product is released on the market a set of safety requirement have to be met to ensure a minimum safety level [12].

A technical requirement for the BSO Bus is the CE marking, more specifically the 2006/42/EC directive on machinery [13]. This document mentions several relevant safety requirements for the present case study, such as:

- General Principles
  - *"The manufacturer of the machinery or his authorized representative must ensure that a risk assessment is carried out in order to determine the health and safety requirements which apply to the machinery" [6].*
- 1.1.2 Principles of safety integration
  - *"Machinery must be designed and constructed so that it is fitted for its function, and can be operated, adjusted and maintained without putting persons at risk when these operations are carried out under the conditions foreseen but also taking into account any reasonably foreseeable misuse thereof" [6].*
  - *"The machinery must be designed and constructed in such a way as to prevent abnormal use if such use would engender a risk. Where appropriate, the instructions must draw the ser's attention to ways-which experience has shown might occur-in which the machinery should not be used" [6].*
- 1.1.5 Design of machinery to facilitate its handling
  - *"Machinery, or each component part thereof, must: be capable of being handled and transported safely, be packaged or designed so that it can be stored safely and without damage" [6].*

The manufacturer of the BSO Bus, currently only the Stintum company, is responsible for strictly following the requirements from the CE marking, the Dutch driver of the Bus is responsible for only use CE marked Buses on public roads.

According to Dutch regulations, one is able to purchase a BSO Bus or any other electric vehicle without CE marking but he is not allowed to drive it on public roads.

3.2.2 Safety requirements of BSO Bus

In order to boost and encourage the development of innovative and electric vehicles such as the BSO Buses, the Dutch government created and approved a law called “exceptional mopeds” [1]. In a nutshell, this document presents some rules that must be followed by vehicles such as the BSO Buses. Some of those rules are:

- Maximum speed of 25km/h
- Has to have 2,3 or 4 wheels
- Does have a combustion engine with a maximum cylinder content of $50\ cm^3$ or an electromotor with the maximum power of 4 kW.
- It is not a vehicle for disabled people
- Do not need a driver’s license
- No registration certificate needed
- No helmet required
- Lights are mandatory, these lights do not have to be attached to the vehicle
- Allowed to drive from an age of 16 years old

Additional safety rules that are applicable to the BSO Buses are:

- The BSO Bus is used as much as possible on separate cycle paths or in 30km/h zones [5].
- The BSO Bus is only driven by people who have followed a driving skills training [5].
- You need to have civil liability insurance.
- If driving on cycle paths follow bicycle rules, lighting signals and road markings. If changing direction activate the turning lights.
- Only one driver at a time is allowed on the BSO Bus. The alcohol limit is 0.5 and the drugs limit is 0.
- Lights must be mounted on the Bus at all time and turned on cloudy, foggy, rainy conditions as well as on nighttime. A white/yellow light is required for the front and a red light for the back. Both lights must be visible at a distance of at least 300m.
- The BSO Bus must be equipped with reflectors on four sided, a white in the front, a yellow or white on each side and a red in the back.
- When carrying passengers, all the children must be seated and wearing the seatbelts at all time
- The total weight, with 10 children and the driver must not exceed 600Kg.

So, for this Bus to become totally legal under Dutch legislation, it has to possess a CE marking, comply with the rules of the “exceptional mopeds” law and with the BSO Bus specific rules.

It is important to mention that due to the fact that BSO Buses will be a new vehicle on Dutch roads, the other road users might take a while to get used to its presence (Figure 7) It will also take a considerable amount of time for both the environment and the human to adapt, in terms of orientation and movement patters. That is why it is so important for this vehicle to comply with the safety rules previously mentioned, otherwise serious penalties and fines can be issued.

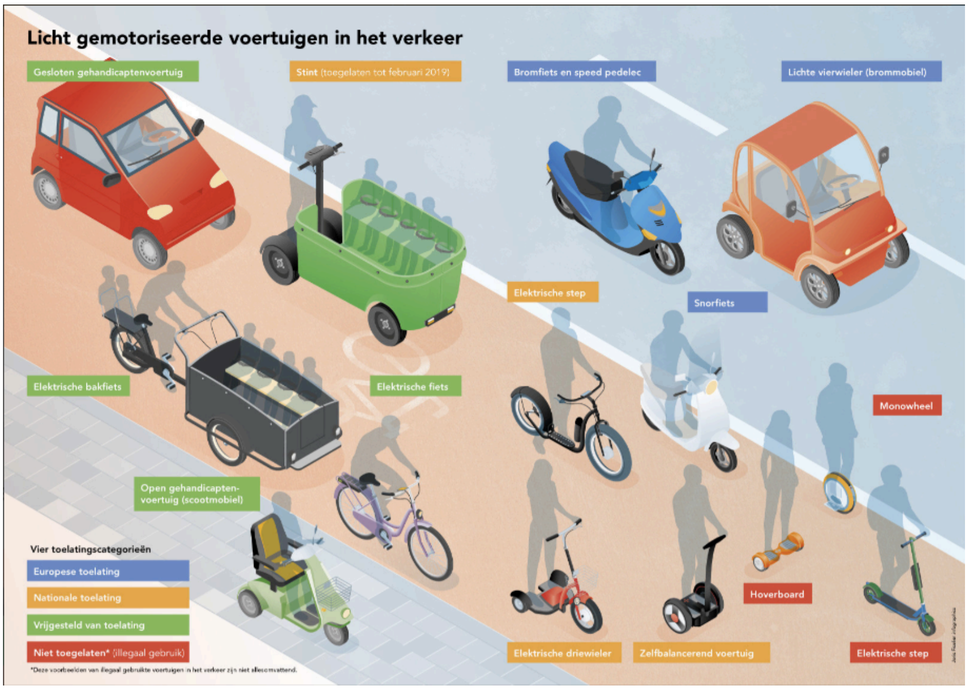

Figure 7 – Safe inclusion of the BSO Bus on Dutch roads [14].

3.3 History of accidents

Although the BSO Buses are only expected to be delivered to the public on the Spring of 2021 [6], it is important to mention that these vehicles were created to tackle and correct the safety problems of its antecessor, the Stint, which actually proved to be fatal in the tragic accident in September 2018.

For the present report, the Stint accident will be further explained, mainly due to the fact that for Stintum, the manufacturer of BSO Buses, it is extremely important to understand what happened and what safety issues must be improved and implemented in the new vehicles.

In addition, there have been reports of incidents involving actual BSO Buses, which are also going to be mentioned.

3.3.1. Oss rail accident

On the morning of 20 September 2018, a Stint – an electric cart equipped for carrying children – was travelling from a child day center to a primary school in Oss. The Stint was carrying five children, ranging in age from four to eleven years. A female employee of the child day care center was driving the vehicle. The journey was problem-free until the level crossing at Braakstraat.

While the level crossing barriers were already lowered, the Stint continued its passage and ended up on the crossing. A passing train collided with the Stint, which was carried sideways several dozens of meters. Four children died. A fifth child and the driver survived but sustained several injuries [14].

According to [4], the team investigating the accident spoke to the childminder and a large number of witnesses and it was concluded that the driver tried to stop the Stint before the railway crossing. However, the braking system failed and therefore the vehicle did not respond ending up hitting the train.

Although an official investigation is yet to be concluded, it was pretty clear that human fault could be discarded.

Some images related to this tragic accident are shown below.

Figures 8 and 9 – Tragic accident involving a Stint vehicle in Oss [15].

3.3.2. Wierden incident

On December 16, 2020, one of the 24 BSO Buses [16] owned by the Columbus Junior childcare center caught fire while parked at the garage of their facilities in Wierden. It is believed that the overheating was due to a malfunction of the battery. An extensive investigation is currently being carried out by Stintum the battery manufacturer, the fire brigade and the insurance. A similar vehicle to the one that was involved in this incident is shown in Figure 10.

Figure 10 – One of Columbus Junior BSO Buses [16]

4. Hazards

In the present chapter, the hazards that are applicable to the System Under Consideration (SUC) BSO Bus are identified, assessed and evaluated according to the Safety by Design principles [7]. Based on the definition of the International Standard for the safety of machinery (ISO 12100) in which a hazard is a “potential source of harm” [18], the Safety by Design process was followed. In addition, the only systems analyzed were the ones with direct influence in a proper functioning of the BSO Bus. Accessory and non-essential systems were not considered.

4.1 Identification of hazards

Firstly, the identification of potential functional, technical and operational hazards in the environment, system and subsystems within the BSO Bus were developed and are shown in Appendix B.

It is important to note that, according to [7], functional aspects focus on the objectives and functions which are needed for the system to satisfy the stakeholders across different levels of a hierarchy and different phases of the life cycle. Technical hazards focus on the design, implementation, production, assembly and installation of the BSO Buses. Operational hazards predominantly focus on interaction of humans with the System Under Consideration and with the environment of the system.

The several hazards identified are based on past events that involved the antecessor of the BSO Bus, including the tragic accident of 2018, but also in future scenarios that can partially be predicted and taken into consideration, knowing that BSO Buses will only be fully commercialized in 2021. The hazards were given a specific sequence of characters, depending on their classification, to facilitate further utilization.

4.2 Risk assessment

After the hazards and potentially hazardous situations of the BSO Bus were identified, their severity and frequency of occurrence was determined according to the different categories presented in Appendix C.

Once this procedure is completed, the hazards are placed in the risk assessment matrix, as shown in Table 4, where the color red indicates high risk, the orange serious risk, the yellow medium, green low and blue eliminated (no risk).

	Catastrophic (1)	Critical (2)	Marginal (3)	Negligible (4)
Frequent (A)		II,		
Probable (B)		III, VII, X, XIII,11	XII	
Occasional (C)	XI, S	8, I, IV, B, T	7,9,10, V, VI, A	
Remote (D)	13, IX	4,5,15, C, M	2,6,14, VII, N, O	J, P, R
Improbable (E)	VIII, E, F	12, K	3, D, G, H, L, Q	I
Eliminated (F)	1			

Table 4 – Risk assessment matrix of BSO Buses.

4.3 Fault tree analysis (FTA)

A fault tree is a graphical model that tells why procedures, processes and systems fail. The main advantage of this method is that different levels of hazards are identified which gives greater details by breaking down larger bits into smaller ones, that essentially are easier to deal with and to interpret.

Based on the outcomes and assessment of the risk identification phase of the BSO Bus, two different fault trees were developed to give a good overview of what may cause the accidents which result in injuries and possibly deaths.

The first one is related to the BSO Bus failure related to vehicular components and the respective occurrence of certain malfunctions.

The second fault tree is related to the failure of BSO Buses due to infrastructure, in which the environment is included. Both fault trees were developed using the software Draw.io and are presented in Appendix D.

5. Control of Hazards

After the risk assessment was performed, it could be concluded that there are some hazards associated to the BSO Bus that possess high or serious risk.

The main purpose of this section is to present a set of actions aimed at eliminating such hazards. However, in situations where the hazards cannot be eliminated at all, the goal is to substantially reduce its frequency of reduction and or severity.

Later on, the solutions presented to tackle the hazardous situations will be analyzed having into account a cost/benefit approach.

5.1 High risks (red)

- **Inexperienced, unqualified or uneducated driver (II):** This particular hazard cannot be totally eliminated but can significantly be reduced if the following measures are implemented:
  - ⇒ More extensive and demanding training classes/sessions
  - ⇒ Select the best and most competent driving instructors
  - ⇒ Stintum provides guidelines for usage
  - ⇒ Insert a fingerprint reader or face recognition system to assess if the driver meets the requirements to drive a BSO Bus

- **Interaction with other reckless drivers (III):** This hazard can be reduced if:
  - ⇒ Upgrade and clarify the current traffic regulations
  - ⇒ Enforce the law more efficiently
  - ⇒ Better educate the other drivers not to be aggressive
  - ⇒ Introduce and encourage the purchase of more self-driven vehicles capable of detecting and avoiding BSO Buses

- **Accidental deactivation of safety features by the driver (VII):** This hazard can arise if, for example, the driver unwantedly, deactivates the emergency brake, the seatbelts, the horn or the lights. If the following measures are followed this hazard can essentially be eliminated or severely reduced.
  - ⇒ Insert beep, buzzer or sound signal to warn the driver
  - ⇒ Develop a two-input required system to deactivate such important features
  - ⇒ Place the buttons/handles in a hidden place, hard to accidentally activate

- **Wrong adjustment of seatbelts (X):** This particular hazard can pretty much be eliminated if the following recommendations are accomplished:
  - ⇒ Provide extra/particular training to the drivers on how to adjust the seatbelts to different children
  - ⇒ Insert images on the inner side of the tub related to properly fasten the seatbelts
  - ⇒ Include a safety card on this regard
  - ⇒ Inform the children about the dangers of having a wrongly adjusted seatbelt
  - ⇒ When fasten the seatbelts on the children, the driver must ask for feedback about the comfort and feeling

- **Children unlock the seatbelt during driving and fall out of the tub (XI):** Due to the fact that the children will ultimately always be the ones to unfasten their seatbelts, it can be said that this hazard cannot be fully eliminated. However, there are some ways to mitigate the hazards.
  - ⇒ Inform the children and their parents about the dangers of unlocking the seatbelts during driving
  - ⇒ Insert loud sound signals if a seatbelt in unfastened
  - ⇒ Automatically activate the emergency button of the BSO Bus to ultimately stop the vehicle

- **Emergency brake is too difficult to use in critical situations (XIII):** This hazard can fully be eliminated is the precautionary measures are followed.
  - ⇒ Provide special training sessions on how to properly reach and activate the emergency brake
  - ⇒ Place the emergency brake within arm reach, in clear sight
  - ⇒ Introduce safety labels indicating the functioning and positioning of the brake
  - ⇒ Properly assess situations where the activation of this brake is mandatory

- **Malfunction or failure of critical technologies such as braking systems, accumulator or electric motor (11):** It is known that a failure or malfunction of a certain subsystem of the BSO Bus can always occur, regardless of the level of technology or equipment. However, if the following steps are followed, the likelihood of such event can be decreased.
  - ⇒ Perform regular and specialized maintenance on the vehicle
  - ⇒ Make rigorous quality tests to the parts and components
  - ⇒ Assess if the temperature limits and environmental conditions are suitable for usage of the vehicle
  - ⇒ Insert parallel or backup systems which take control when this hazard is present

- **Structural failure in components due to lack of maintenance (S):** Although this hazard cannot be eliminated, because the maintenance work can be unproperly done, it is safe to say that the reduction of the risk can easily occur if certain recommendations are followed.
    - ⇒ Sound message informing of coming maintenance date
    - ⇒ Written information on the vehicle informing the driver of due maintenance
    - ⇒ Automatically halt if maintenance is overdue
    - ⇒ Stintum informed directly through the vehicle if maintenance deadlines are approaching

5.2 Evaluation of solutions concerning cost and benefit

From analyzing the suggested measures and solutions to the high-risk hazards, it is possible to conclude that there are same solutions that apply to different hazardous situations, such as the instruction and education of the driver to cope with different scenarios.

In addition, it is also fair to say that some of the suggestions cost more and produce better benefits than others. Exemplifying, the development of a stand-on platform sensor capable of analyzing the driving competences of a driver seems to be an extremely futuristic option, with possible great results, but also with an enormous investment. On the other hand, the existence of safety labels such as cards, user's manual or driver's guidebooks appear to be a more realistic approach given the cost reality of a vehicle such as the BSO Bus.

To better understand the cost and benefit scope of each presented solution it was developed a table for each hazard containing an evaluation, in a scale from 1 to 10 regarding both aspects, which is presented in Appendix E.

6. Monitor System

6.1 Leading and lagging safety indicators

To measure the safety of a system, safety indicators can be applied. Such indicators are tools used to measure the safety performance of a system by measuring the total end result of the safety, as well as the prevention of accidents.

According to [19], safety indicators can be divided into leading or lagging indicators.

Lagging indicators define the safety by measuring accidents from the past and its statistics. Some examples include injury frequency and severity, lost workdays and worker's compensation costs [19].

On the other hand, leading indicators focus on future safety performance by measuring activities and events that prevent accidents from occurring. Some examples are safety training, employee perception surveys and safety audits [19].

Comparing both indicators, it can be said that leading ones are more advantageous due to the fact that accidents do not have to happen for the safety to be properly measured.

6.2 Lagging indicators for BSO Buses

In the particular case of BSO Buses, lagging indicators would include the number of collisions and incidents involving such vehicles and the data related to it.

However, due to fact that BSO Buses are extremely recent and have only began to circulate Dutch roads in December 2020, it is fair to say that there is not relevant data available online about the actual accidents involving these vehicles.

As time passes and BSO Buses become a regular presence on Dutch roads it is expected that hospitals and the government's traffic safety department begin to collect information and publish it online.

As of now, instead of relying on concrete and official data, it is only possible to suggest some lagging safety indicators for the System of Interest:

- Number of accidents
- Number of accidents caused by the Human, Technical System and Environment
- Number of accidents involving (fatal) injuries
- Amount of (fatal) injured road users/cyclists/pedestrians
- Number of violations of the road regulations
- Number of accidents happening under specific weather conditions (rain, snow, ice, hail)

6.3 Leading indicators for BSO Buses

It can be said that leading indicators are much more applicable to the present reality of BSO Buses than lagging ones, mainly due to the fact that these vehicles are recent on the roads and there are no accidents data to analyze.

Some of the suggested safety leading indicators applied to BSO Buses and their explanation are presented in Table 5.

Leading safety indicator	Explanation
Measuring road roughness and friction	As analyzing in Section 4.1, road conditions are a hazard of BSO Buses. Therefore, if all the vehicles could measure this indicator and provide the data to Stintum, the manufacturer could perform improvements on the wheels, making them more robust and versatile.
Measuring the amount of training a driver is given before driving the Bus	Also by looking at Section 4.1, it is possible to state that human factor plays an important role in the occurrence of accidents. With this indicator, possible accidents can be avoided, and safety can be increased.
Improved information to the users on how to safely drive a BSO Bus on public roads and bicycle lanes	The manufacturer (Stintum) can make better and more material on how one can use their product safely. This information can be passed on to reseller stores or even maintenance shops that have more contact with the client.
Number of safety announcements/commercials regarding BSO Bus safety	Through this method the BSO Bus stakeholders can better be reached out and therefore safety awareness can more efficiently be reached.
Improve product development cycle	Stintum can look more closely at their development cycle and apply safety analysis to avoid designs that increase usage risk.
Practical education for children and teenagers at schools	Practical education for children and teenagers, the new generation of possible soon to be BSO Bus drivers, would affect the future driving culture and potentially reduce the risk over the years.

Table 5 – Leading safety indicators of BSO Buses.

The goal of these leading indicators is essentially to increase the awareness of this new vehicle, both from the driver and users' point of view, but also from the environment perspective (other road users and adaptability of road signs, for example), in order to change the current safety culture.

7. Prove of Safety

The safety objective of the present report is to improve the safety for BSO Bus that will be mass implemented on Dutch roads. This section will therefore prove that such goal was accomplished.

The main tasks developed in this work, such as the proper definition of the System Under Consideration, the enunciation of safety objectives, the hazard identification and mitigation all result in a safety case. Such case is aimed at proving the safety of the system, through justified and relevant arguments supported by evidence and concrete facts.

The Goal Structuring Notation (GSN) developed by Tim Kelly, at the University of New York [20], will be used to prove that the system is actually safe. GSN is a graphical notation that makes the system case easier to read, interpret and visualize when compared to the conventional text. In addition, in clearly shows the goals, arguments and evidence.

The GSN Model applied to the present case study of BSO Buses is presented in Figure 11.

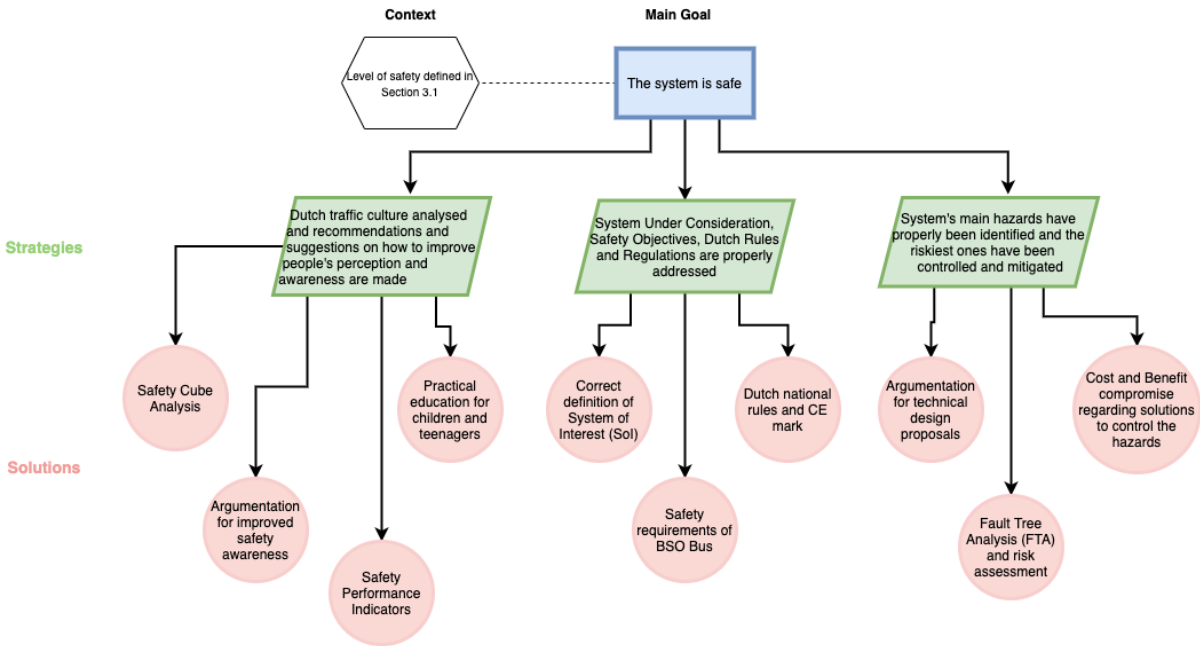

Figure 11 – GSN Model of the BSO Bus.

Overall, it can be said that Figure 11 represents the safety case of this individual report. To start with, the main goal that is intended to be achieved is depicted on blue on the top of the diagram.

To prove that the safety of BSO Buses is reached, three different strategies are suggested and are represented in green. Each strategy possesses multiple solutions trying to ensure the safety of the System Under Consideration. Such solutions come from all the work developed throughout this document.

Taking everything into consideration, it can be concluded that the system is safe. The main safety objective has been reached through the implementation of safety strategies. This resulted in an increased level of safety for BSO Buses on Dutch roads and cycle paths.

Mainly due to the tragic accident involving a Stint, many people and politicians have expressed their criticism and skepticism regarding the BSO Buses, which is understandable because it is a vehicle used to transport small children.

However, the manufacturer of BSO Buses has taken the precautionary safety measures to prevent such accident from happening again, so the population should believe in the reliability and safety of these vehicles.

8. Reflection

Despite being an Erasmus + exchange student from Porto, Portugal, studying Mechanical Engineering with the Master's specialization in Production Management, following the course of Safety by Design was without a doubt an enriching experience.

Although my background is totally different from the majority of the students on this course, I am very grateful to have had the opportunity to interact, even online, with these people, in search of a common goal, which was grasping the subjects taught in the course. The problem-solving mindset is the same for any engineer which makes sharing experiences and knowledge very captivating.

In addition, in my home country the students in my faculty rarely communicate between themselves and with the professors in another language other than Portuguese. So, this was also an excellent opportunity to improve my English.

Throughout the Safety by Design journey, the most interesting learning experiences to me were the safety cube theory, that I had never heard of, the seven level of integration represented in the Integration Rainbow and the risk reduction process, that I never thought could be directly applied to a given product.

Regarding the main takeaways from this experience, I must highlight the fact that safety aspects are present in everything, material or not, that we do in our daily lives. So, it is extremely important to follow the safety requirements, process them and fulfill them, to avoid accidents, some of which that are further investigated in Professor's Mohammad Nejad website of Product Safety. Also, after following this course I grasped the board set of tools and approaches on how to address safety issues.

It really is a pity that we did not have the possibility of having face-to-face classes, that could result in a little bit more interaction. The excursion was also something that I was looking forward to but, unfortunately, due to health and safety reasons (COVID-19) did not take place.

To sum up with, although this course is not directly aimed at students like me, I firmly believe that the skills I learned will be useful to me not only in my professional life as a mechanical engineer but also in everyday situations.

One last word of appreciation for Professor Mohammad Nejad, not only for all the work that he has put into his book, website and materials made available to the students, but also for his will to help and assist the students in the best way possible.

9. References

[1] VERSCHUREN, Ymke; HELLEGIEN, Loes; KUIPER, Kaitlyn, “The Stint, Bounded by Innovation”. Accessed: December 30, 2020. [Online]. Available: https://canvas.utwente.nl/courses/6152/files/2007863?module_item_id=194939

[2] “Oss rail accident”, Wikipedia the Free Encyclopedia. Accessed: December 30, 2020. [Online]. Available: https://en.wikipedia.org/wiki/Oss_rail_accident

[3] “Dutch ban electric child cart after Oss rail deaths”, October 2, 2018. Accessed: December 30, 2020. [Online]. Available: https://www.bbc.com/news/world-europe-45717871

[4] “Driver not to blame in Stint accident that killed four kids”, Thursday, July 4, 2019, NLTimes. Accessed: December 30, 2020. [Online]. Available: https://nltimes.nl/2019/07/04/driver-blame-stint-accident-killed-four-kids

[5] “Minister Van Nieuwenhuizen gives the green light for ‘new Stint’”, October 7, 2020, AD. Accessed: December 30, 2020. [Online]. Available: https://www.ad.nl/binnenland/minister-van-nieuwenhuizen-geeft-groen-licht-voor-nieuwe-stint~a8ed8aed/

[6] “BSO Bus (new Stint) – news”, Boink. Accessed: December 30, 2020. [Online]. Available: https://www.boink.info/actueel-agenda/stint-bsobus

[7] Nejad, N. M. (2020). *Safety by Design Engineering Products and Systems*

[8] “BSO Bus”, stintum. Accessed: December 30, 2020. [Online]. Available: https://stintum.com/bsobus/

[9] “BSO bus”, stint Urban Mobility. Accessed: December 30, 2020. [Online]. Available: https://stintum.com/wp-content/uploads/2020/11/2020-Brochure_BSO-bus_NP.pdf

[10] “Technical Specification”, stint. Accessed: December 31, 2020. [Online]. Available: https://stintum.com/veiligheid/

[11] “Road safety”, Government of the Netherlands. Accessed: January 1, 2021. [Online]. Available: https://www.government.nl/topics/mobility-public-transport-and-road-safety/road-safety

[12] “CE marking”, European Commission. Accessed: January 1, 2021. [Online]. Available: https://ec.europa.eu/growth/single-market/ce-marking

[13] “machinery”, EUR-Lex Access to European Union law. Accessed: January 1, 2020. [Online]. Available: https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02006L0042-20091215

[14] “Safe admittance onto the public roads – Lessons learned from the Stint accident”, October 16, 2019, Dutch Safety Board. Accessed: January 2, 2021. [Online]. Available: https://www.onderzoeksraad.nl/en/page/12408/safe-admittance-onto-the-public-roads---lessons-learned-from-the

[15] “Dutch rail crash: Four children killed in electric cart”, September 20, 2018, BBC News. Accessed: January 2, 2021. [Online]. Available: https://www.bbc.com/news/world-europe-45586492

[16] “News: Here is the CoBus”, December 15, 2020, kinderopvang columbus junior. Accessed: January 2, 2021. [Online]. Available: https://www.columbusjunior.nl/nieuws/nieuwe-bso-bussen-cobus

[17] “Replacement infamous Stint already catches fire before first use”, December 16, 2020, Ruetir. Accessed: January 2, 2021. [Online]. Available: https://www.ruetir.com/2020/12/16/replacement-infamous-stint-already-catches-fire-before-first-use/

[18] “ISO 12100:2010(en) Safety of machinery – General principles for design – Risk assessment and risk reduction”, ISO. Accessed: January 2, 2021. [Online]. Available: https://www.iso.org/obp/ui/#iso:std:iso:12100:ed-1:v1:en

[19] MIDDLESWORTH, Mark, “A Short Guide to Leading and Lagging Indicators of Safety Performance”, April 24, 2020, ErgoPlus. Accessed: January 5, 2021. [Online]. Available: https://ergo-plus.com/leading-lagging-indicators-safety-preformance/

[20] NEJAD, Rajabali Mohammad Dr, “Safety by Design Evidences and Arguments for Reporting Safety”, University of Twente. Accessed: January 7, 2021. [Online]. Available: https://canvas.utwente.nl/courses/6152/files/2071749?module_item_id=201402

Appendixes

Appendix A – Design Structure Matrices

Human	Owners	Drivers	Insurance companies	Auto repair shops	Stintum	Daycare management	Users	Parents
Owners		Give permission	Paying insurance	Paying maintenance procedures	Buying Bus	Assigning responsibility		Inform
Drivers			Paying insurance	Providing feedback		Complying with rules	Responsible for	
Insurance companies	Providing help in case of accidents	Providing help in case of accidents		Direct damaged vehicles	Performing technical opinion	Informing about deadlines	Create special insurances for children	Present documents
Auto repair shops	Providing safe, working vehicle	Providing safe, working vehicle	Give result of technical opinion		Receive original parts	Direct bills and payments		
Stintum	Providing safe, working vehicle	Providing safe, working vehicle		Provide original and trustworthy parts and components		Ask for feedback and opinions	Have into account users age	
Daycare management	Forward payment receipts	Assigning the driver	Receiving bills	Receiving bills				
Users		Respect and obey			Comply with the rules			
Parents	Known	Assigning trust	Sign documents		Know the rules and risks			

Table A.1 – Human Interaction.

Technical System	Steering Wheel	Braking systems	Accumulator	Electric motor	Lighting	Wheels	Frame and tub	Controls
Steering Wheel			Electricity			Forces on steering when driving	Provides mounting points	
Braking systems	Provides mounting points					Forces		Regulates braking forces
Accumulator				Regenerated electricity			Provides mounting points	
Electric motor		Signal to change battery	Electricity				Provides mounting points	Regulates thrust and velocity
Lighting			Electricity				Provides mounting points	Switches On/Off
Wheels	Direction	Brakeforce		Thrust and torque			Provides mounting points	
Frame and tub		Force on frame and tub		Force on frame and tub		Force on frame and tub		
Controls			Battery level indication	Velocity indication	Feedback information		Provides mounting points	

Table A.2 – Technical System Interaction.

Environment	Weather	Infrastructure	Other road users	Laws and Policies
Weather				
Infrastructure	Road conditions/Visibility		Usage wear	Dutch laws and regulations
Other road users	Weather conditions	Signs and road markings		Dutch laws and regulations
Laws and Policies			Feedback and opinion	

Table A.3 – Environment Interaction.

Steering Wheel	Owns	Steers			Produces			
Braking System	Owns	Applies		Maintain	Produces			
Accumulator	Owns			Maintain	Produces			
Electric motor	Owns				Produces			
Lighting	Owns	Turns On/Off		Maintain	Produces			
Wheels	Owns			Maintain	Produces			
Frame and tub	Owns	Stands on			Produces		Sits on	
Controls	Owns	Gives input			Produces			
Technical System/Human	**Owners**	**Drivers**	**Insurance companies**	**Auto repair shops**	**Stintum**	**Daycare management**	**Users**	**Parents**

Table A.4 – Technical System – Human Interaction.

Steering Wheel				
Braking System	Adjusting	Adjusting		
Accumulator				Ensure quality
Electric motor				Ensure quality
Lighting	Weather adaptable lights		Respectful towards others	Ensure quality
Wheels	Variable grip in dry/wet/icy conditions	Variable grid on different road surfaces		In conformance
Frame and tub	Capable to withstand water, hail and snow	Capable to withstand constant vibrations and twists		Within measures
Controls				Ensure quality
Technical System/Environment	**Weather**	**Infrastructure**	**Other road users**	**Laws and Polices**

Table A.5 – Technical System – Environment Interaction.

Owners				
Drivers	Operation conditions	Traffic and accidents	Operation conditions	Operation restrictions
Insurance companies				
Auto repair shops				
Stintum	Requirement input	Requirement input		Design and adjust regulations
Daycare management				
Users			Respect	Comply and obey
Parents				
Human/Environment	**Weather**	**Infrastructure**	**Other road users**	**Laws and Polices**

Table A.6 – Human – Environment Interaction.

Appendix B – Identified hazards in BSO Buses

Environment	Technical System	Subsystems
1. Tilt protection do not meet regular safety standards due to new design 2. Temperature of the environment above or below the operational limits of the BSO Bus 3. Electrical power supply is affected by close electrical fields	4. Malfunction or failure of the onboard computer/electronic system 5. Malfunction or failure of safety protocols during unusual safety situation 6. Impossibility to stop/control electric power supply 7. Excessive weight in the vehicle increasing the minimum required braking distance 8. Impossibility to push the vehicle in an emergency situation	9. Direction lights, braking lights, sensors or horn can be broken, resulting in failure to communicate with other road users 10. Automated subsystems not able to apply the required force needed to actuate subsystems such as the braking system and the steering wheel 11. Malfunction or failure of critical technologies, such as braking systems, accumulator or electric motor 12. Accidentally drive backwards, when wanting to drive forward 13. Failure in the thrust handle with the consequence that the driver is not capable of adjusting the speed 14. Breaking or losing the key to the vehicle during driving and the vehicle continues to drive 15. Malfunction in the stand-on platform sensor, which instantly jams the vehicle

Table B.1 – Functional Hazards of BSO Bus.

Environment	Technical System	Subsystems
I. Compromised/damaged road signs, road marks, traffic lights that are unproperly interpreted by the driver II. Inexperienced, unqualified or uneducated drivers. III. Interaction with other reckless vehicle drivers IV. Driver does not pay attention to the surroundings because he is distracted with the children V. Low visibility due to tilt bars and roofs/accessories in the vehicle	VI. Driver does not take control of the vehicle when needed VII. Accidental deactivation of safety features by the driver VIII. Children are capable of interfering and controlling the BSO Bus	IX. Accidental activation or deactivation of important driving features by the children or driver X. Wrong adjustment of seatbelts XI. Children unlock the seatbelt during driving and fall out of the tub XII. Failure to use the lights, specially turning lights XIII. Emergency brake is too difficult to use in critical situations

Table B.2 – Operational Hazards of BSO Bus.

Environment	Technical System	Subsystems
A. Slippery or icy roads compromising the response of the system or subsystems B. Roads, cycle paths, road signs, road markings, other road users, pedestrians or other vehicles not detected due to lack of visibility in harsh weather conditions C. Incorrect repairs are done to the Bus due to incompetent or unexperienced or untrained mechanicals/repair D. Defects in the parts provided by the manufacturer E. Park near a busy area or road F. Big chance of colliding with a child near schools	G. Damaged on-board computer due to its unprotected location H. The system cannot withstand malfunctions of subsystems I. The software of the BSO Bus is heavily compromised or even hacked J. The system is not updated with the required upgrades K. Not able to properly communicate the actual information of the subsystems L. Collection of data compromised or wrongly done M. Not able to communicate malfunctions and problems to the driver N. Due to unconventional measurements of the vehicle, the driver can easily lose control of the vehicle and other drivers can be obstructed O. It is hard to anticipate the movements and actions of a BSO Bus	P. Sensors, horn, etc. misplaced within the vehicle or even loose Q. Subcomponents were not designed properly to withstand certain operational conditions (temperature, weather, wind, rain, etc.) R. Seats are not adjustable to different children sizes S. Structural failure in components due to lack of maintenance T. Hand brakes cables get loose or stuck

Table B.3 – Technical Hazards of BSO Bus.

Appendix C – Hazard mitigation categories

Severity Categories		
Description	**Severity Category**	**Result Criteria**
Catastrophic	1	Could result in one or more of the following: death, permanent total disability, irreversible significant environmental impact, or monetary loss equal to or exceeding $10M.
Critical	2	Could result in one or more of the following: permanent partial disability, injuries or occupational illness that may result in hospitalization of at least three personnel, reversible significant environment impact, or monetary loss equal to or exceeding $1M but less than $10M.
Marginal	3	Could result in one or more of the following: injury or occupational illness resulting in one or more lost workday(s), reversible moderate environmental impact, or monetary loss equal to or exceeding $100K but less than $1M
Negligible	4	Could result in one or more of the following: injury or occupational illness not resulting in a lost workday, minimal environmental impact, or monetary loss less than $100K.

Table C.1 – Severity categories.

Probability Levels		
Description	**Level**	**Likelihood**
Frequent	A	Likely to occur often in the life of an item
Probable	B	Will occur several times in the life of an item
Occasional	C	Likely to occur sometime in the life of an item
Remote	D	Unlikely, but possible to occur in the life of an item
Improbable	E	So unlikely, it can be assumed occurrence may not be experienced in the life of an item
Eliminated	F	Incapable of occurrence.

Table C.2 – Probability levels.

Appendix D – Fault tree analysis (FTA)

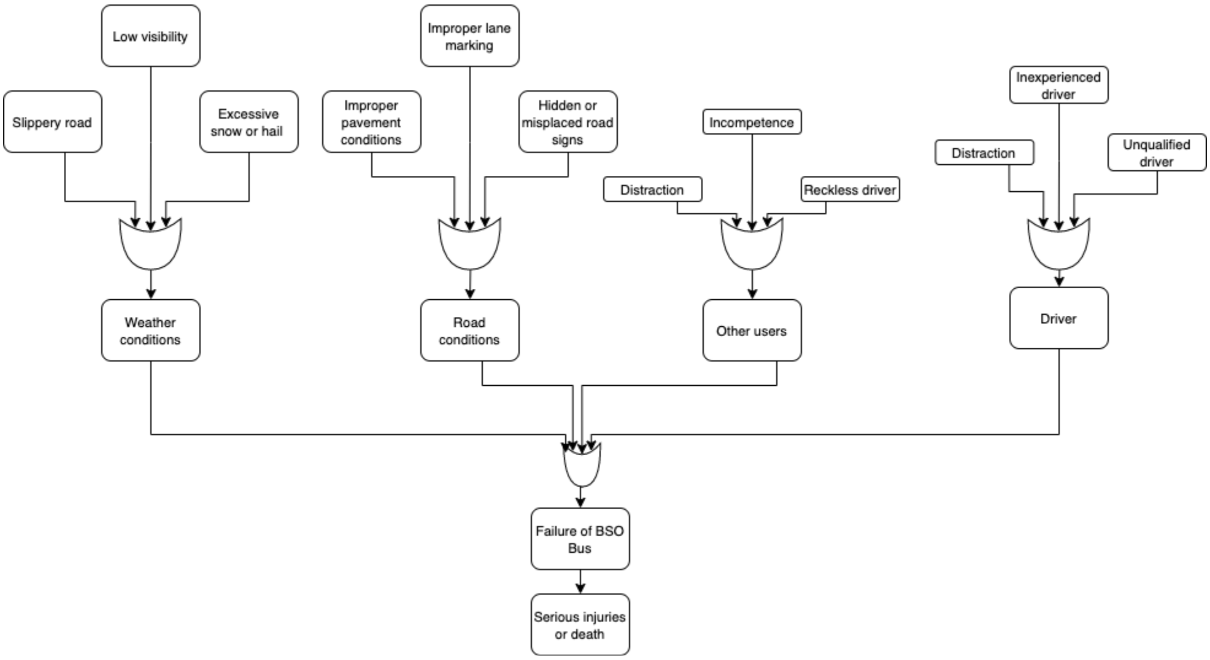

Figure D.1 – Fault Tree Analysis of BSO Buses failure related to infrastructure.

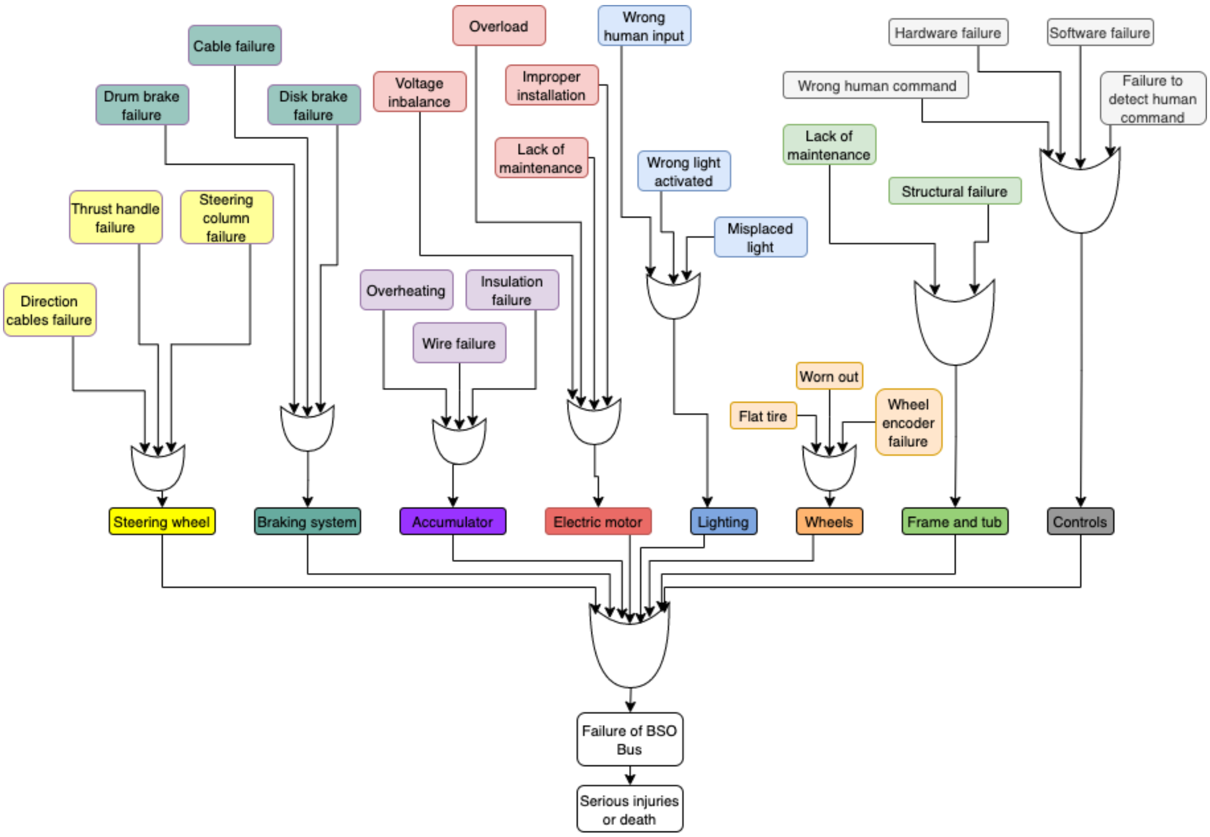

Figure D.2 – Fault Tree Analysis of BSO Buses related to vehicular components.

Appendix E – Cost and benefit analysis of risk mitigation solutions

Appendix E.1 – Inexperienced, unqualified or uneducated driver (II)

Solution	Cost (0-10)	Benefit (0-10)	Explanation
More extensive and demanding training classes/sessions	4	7	*Having into account a cost-effective scenario, this proves to be the best solution*
Select the best and most competent driving instructors	5	5	*Choosing the best professionals over the remaining ones is seen as not significant to ensure a competent driver*
Stintum provides guidelines for usage	3	6	*A very attractive option, to just ask the manufacturer for some additional information*
Insert a fingerprint reader or face recognition system to assess if the driver meets the requirements to drive a BSO Bus	8	10	*By far the most expensive solution for this particular hazard, but also the most beneficial. The vehicle would not be started if the driver was not previously approved.*

Table E.1 – Solutions to mitigate the risks associated to hazard number II.

Appendix E.2 – Interaction with other reckless drivers (III)

Solution	Cost (0-10)	Benefit (0-10)	Explanation
Upgrade and clarify the current traffic regulations	6	4	*Costly and not so beneficial because many drivers tend to disrespect road signs and rules*
Enforce the law more efficiently	7	5	*To punish aggressive attitudes towards others on the roads would require a massive investment, that would obviously not detect all infractions*
Better educate the other drivers not to be aggressive	4	9	*The best option because it is possible to inform and educate drivers through advertisements and commercials, which is not that expensive*
Introduce and encourage the purchase of more self-driven vehicles capable of detecting and avoiding BSO Buses	9	7	*The most expensive solution, and sometimes not so advantageous because the BSO Buses drive on bicycle lanes*

Table E.2 – Solutions to mitigate the risks associated to hazard number III.

Appendix E.3 – Accidental deactivation of safety features by the driver (VII)

Solution	Cost (0-10)	Benefit (0-10)	Explanation
Insert beep, buzzer or sound signal to warn the driver	4	6	*Considered to be the most affordable option, due to its practicality. However, it is seen as the least beneficial, because the driver may not listen to it, due to environmental noise or the children talking and yelling*
Develop a two-input required system to deactivate such important features	5	8	*Seen as the best option overall. For the manufacturer it is not that difficult to develop an extra input for the function and the likelihood of simultaneously activate both inputs is reduced*
Place the buttons/handles in a hidden place, hard to accidentally activate	5	7	*Affordable to the manufacturer and beneficial, although the irreverence of the child can lead to its location being found*

Table E.3 – Solutions to mitigate the risks associated to hazard number VII.

Appendix E.4 – Wrong adjustment of seatbelts (X)

Solution	Cost (0-10)	Benefit (0-10)	Explanation
Provide extra/particular training to the drivers on how to adjust the seatbelts to different children	5	9	*A competent driver is more than halfway to having the seat belts properly secured*
Insert images on the inner side of the tub related to properly fasten the seatbelts	2	4	*Although being theoretically acceptable, in real cases, children will neglect, cover or damage such images*
Include a safety card on this regard	1	3	*This solution in practical situation may not prove to be that good, mainly because the users tend to disregard these instruction cards.*
Inform the children about the dangers of having a wrongly adjusted seatbelt	0	5	*This solution does not have significant costs associated, but the children being immature and naïve may not take such risks seriously*
When fasten the seatbelts on the children, the driver must ask for feedback about the comfort and feeling	0	10	*This option is deemed as the best, because each child is different and has distinct needs*

Table E.4 – Solutions to mitigate the risks associated to hazard number X.

Appendix E.5 – Children unlock the seatbelt during driving and fall out of the tub (XI)

Solution	Cost (0-10)	Benefit (0-10)	Explanation
Informing the children and their parents about the dangers of unlocking the seatbelts during driving	0	5	*Although cost free, this solution can turn out to be not so effective, due to losses of information or, more importantly, misinterpretations by the children*
Insert loud sound signals if a seatbelt is unfastened	4	7	*Probably the best option overall. For Stintum the insertion of such device is not that costly, and the driver can easily be alerted to the situation and stop the Bus*
Automatically activate the emergency button of the BSO Bus to ultimately stop the vehicle	8	9	*Extremely expensive technology to implement on BSO Buses, but with pleasant and reliable outcomes.*

Table E.5 – Solutions to mitigate the risks associated to hazard number XI.

Appendix E.6 – Emergency brake is too difficult to use in critical situations (XIII)

Solution	Cost (0-10)	Benefit (0-10)	Explanation
Provide special training sessions on how to properly reach and activate the emergency brake	5	8	*This solution is considered to be the best overall. Once again, by providing a proper training to the driver they will now how to access and activate the brake*
Place the emergency brake within arm reach, in clear sight	3	5	*Although cheap for Stintum, the fact that is visible and easy to handle can lead to false activations*
Introduce safety labels indicating the functioning and positioning of the brake	1	3	*This alternative is not that viable overall, because in emergency situation the driver will not lose time looking at the label*
Properly assess situations where the activation of this brake is mandatory	0	9	*Together with the effective training, this is one of the best solutions*

Table E.6 – Solutions to mitigate the risks associated to hazard number XIII.

Appendix E.7 – Malfunction or failure of critical technologies such as braking systems, accumulator or electric motor (11)

Solution	Cost (0-10)	Benefit (0-10)	Explanation
Perform regular and specialized maintenance on the vehicle	4	6	*Increase the frequency of maintenance operations can be the easiest approach to this vehicle, due to moderate costs and considerable benefits.*
Make rigorous quality tests to the parts and components	6	7	*Improve the quality tests of Stintum might be the best option. Increase the standards and criteria would reduce the likelihood of failure or malfunction*
Assess if the temperature limits and environmental conditions are suitable for usage of the vehicle	2	5	*Although very affordable, this approach can be risky, because during a small period of time the temperature and weather conditions can easily vary and become inadequate to BSO Bus*
Insert parallel or backup systems which take control when this hazard is present	8	9	*By far the most expensive option because it requires major changes in the BSO Bus design. It would also require the insertion of a new technology, not that suitable for the cost reality of BSO Buses. Obviously, the benefits would be huge*

Table E.7 – Solutions to mitigate the risks associated to hazard number 11.

Appendix E.8 – Structural failure in components due to lack of maintenance (S)

Solution	Cost (0-10)	Benefit (0-10)	Explanation
Sound message informing of coming maintenance date	2	7	*Probably the best solution overall for the BSO Bus reality. If the message is really loud, the driver will eventually realize and direct the vehicle to the garage.*
Written information on the vehicle informing the driver of due maintenance	1	5	*Not so practical, because the driver might not pay attention or disregard and later forget to take the precautionary measures*
Automatically halt if maintenance is overdue	7	7	*Extremely expensive technology given the circumstances, but equally beneficial*
Stintum is informed directly through the vehicle if maintenance deadlines are approaching	8	9	*Also, very expensive. A communication highly developed system would be necessary, which is not viable. Obviously that if it happened, Stintum would perform the maintenance work.*

Table E.8 – Solutions to mitigate the risks associated to hazard letter S.