Development of the Investment Case to Reduce Road Traffic Injuries among Adolescents

Tanzania Road Safety Case Study

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Introduction

This case study on the road safety situation in Tanzania has been undertaken to illustrate how more detailed information on a country can be used to better inform an investment case on the introduction of a set of interventions to reduce road traffic deaths and serious injuries among adolescents. The study contains a review of the road safety situation in Tanzania, a description of Government regulations and performance reviews, as well as a description of road infrastructure and the motor vehicle fleet, the causes of road accidents and fatalities, and other information relevant to modelling an investment case.

The information gathered together is used to refine the assumptions and data for the Road Safety Intervention Model (RSIM) to estimate the impact of a range of interventions on road traffic fatalities and injuries in Tanzania. The RSIM is described in detail in the main body of the report to FIA Foundation. The set of interventions used in the modelling is shown in Table 1.

Table 1: Intervention summary

	Intervention	Base rate	Effective reduction
Motor cycles	Helmets	40%	36%
	Alcohol enforcement	0%	5%
	Infrastructure	See Table 9 and Table 10	46%
	Speed compliance	0%	14%
	Public awareness and education	0%	4.5%
	Graduated licensing scheme 15–19	0%	20%
	Graduated licensing scheme 20–24	0%	4%
Motor vehicles	Seat belts	60%	20%
	Alcohol enforcement	0%	5%
	Infrastructure	See Table 9 and Table 10	39%
	Speed compliance	0%	14%
	Graduated licensing scheme 15–19	0%	20%
	Graduated licensing scheme 20–24	0%	4%
	NCAP	0%	1%
	Public awareness and education	0%	4.5%
Cyclists	Alcohol enforcement	0%	5%
	Infrastructure	See Table 9 and Table 10	52%
	Speed compliance	0%	14%
	Public awareness and education	0%	4.5%
Pedestrians	Alcohol enforcement	0%	5%
	Infrastructure	See Table 9 and Table 10	47%
	Speed compliance	0%	14%
	Public awareness and education	0%	4.5%
All	Capacity building	N/A	N/A

The bulk of this report is a series of graphs comparing deaths and serious injuries under the baseline with those under the intervention scenario. Separately for males and females in three age groups of 10 to 14, 15 to 19 and 20 to 24, graphs are given for deaths and injuries for pedestrians, cyclists, motorcyclists, motor vehicle occupants, and in total in both urban and rural settings.

The results for each age cohort are similar with motor vehicle occupants and pedestrians making up the vast majority of fatalities for both males and females. However, the difference between urban and rural fatalities is forecast to be significant. Urban fatalities are projected to increase dramatically for both males and females, whereas rural fatalities show male fatalities plateauing and females slightly increasing across all age cohorts. This is primarily driven by the increasing urbanisation of

Tanzania as the fatality rates are all slightly decreasing for 10 to 14 year olds for all modes for both genders. The same is not true for 15 to 19 and 20 to 24 year olds, as male modes show a decreasing fatality trend, while most modes show an increase for females.

The results for serious injuries differ significantly from fatalities, with there being more than 10 times as many serious injuries as fatalities and increasing at a greater rate than fatalities. So by 2050, serious injuries are expected to be more than 16 times the number of fatalities. Well over half of all serious injuries occur to cyclists, while pedestrian and motor vehicle occupants represent much smaller levels. The proportion of cyclists decreases through increasing age cohorts (male 10 to 14 ~60%, female 55%, male and female 15 to 19 ~50%, male and female 20 to 24 ~45%), with motor vehicles and pedestrians increasing as cyclists decrease. Nearly all modes for males for 10 to 14 and 15 to 19 year olds show an increasing serious injury rate trend, with declining trends for 20 to 24 year olds from a very high level. This is unexpected as in most settings the 20 to 24 year old age cohort has the highest rates of fatalities and serious injuries with increasing trends. This differs from females who show an increasing serious injury trend for all modes across all age cohorts.

The modelling predicts the number of deaths and serious injuries averted due to the interventions for males and females in the three age groups, as well as the total. The effect of implementing all interventions leads to a 59.9% reduction in annual fatalities by 2030, when they are fully implemented, and a 59.4% reduction in serious injuries (Table 2 and Table 3). The reduction in fatalities and serious injuries over the period 2022 to 2030 is shown in Tables 4 and 5.

Table 2: Percentage reduction in fatalities and serious injuries due to interventions, annual by 2030

	10 to 14	15 to 19	20 to 24	Total
Deaths averted				
Male	58.0%	62.6%	59.0%	60.2%
Female	57.1%	61.7%	57.2%	58.9%
Persons	57.7%	62.4%	58.7%	59.9%
Disability averted				
Male	59.4%	60.7%	59.1%	59.8%
Female	58.1%	59.5%	57.6%	58.4%
Persons	58.9%	60.4%	58.8%	59.4%

Table 3: Annual reduction in fatalities and serious injuries due to interventions

	10 to 14	15 to 19	20 to 24	Total
Deaths averted				
Male	109	286	334	728
Female	70	95	75	240
Persons	178	381	408	968
Disability averted				
Male	1,963	3,210	3,428	8,601
Female	1,295	1,167	896	3,358
Persons	3,257	4,378	4,325	11,960

Table 4: Percentage reduction in fatalities and serious injuries due to interventions aggregated, 2022–2030

	10 to 14	15 to 19	20 to 24	Total
Deaths averted				
Male	43.7%	48.1%	45.2%	46.1%
Female	43.3%	47.7%	44.3%	45.3%
Persons	43.5%	48.0%	45.1%	45.9%
Disability averted				
Male	45.2%	46.5%	45.3%	45.7%
Female	44.3%	45.8%	44.7%	44.9%
Persons	44.9%	46.3%	45.2%	45.5%

Table 5: Aggregated reduction in fatalities and serious injuries due to interventions, 2022–2030

	10 to 14	15 to 19	20 to 24	Total
Deaths averted				
Male	719	1,881	2,100	4,700
Female	451	608	450	1,509
Persons	1,170	2,490	2,550	6,210
Disability averted				
Male	12,000	20,107	20,832	52,938
Female	7,887	7,094	5,199	20,181
Persons	19,887	27,201	26,031	73,119

This information along with the costs of the interventions modelled is incorporated within the economic model described in detail in the main body of the report. The economic benefits associated with the reduced deaths and disability are compared to the costs and expressed in terms of benefit-cost ratios. The results are shown in Table 6 that highlights the large return on investment with a benefit-cost ratio at 3% discount of 2.6 for fatalities only, but 38.3 if serious injuries are included.

Table 6: Economic analysis of interventions

		2%	3%	5%	0%
Economic benefit, million USD (NPV)	Deaths	2,334	1,591	796	5,442
Economic benefit, million USD (NPV)	Disability	31,897	21,498	10,525	76,115
Economic benefit, million USD (NPV)	Deaths plus disability	34,231	23,089	11,321	81,557
Cost, million USD (NPV)		677	603	485	868
Benefit-cost ratio					
Economic benefit	Deaths	3.4	2.6	1.6	6.3
Economic benefit	Deaths plus disability	50.6	38.3	23.3	94.0

Tanzania

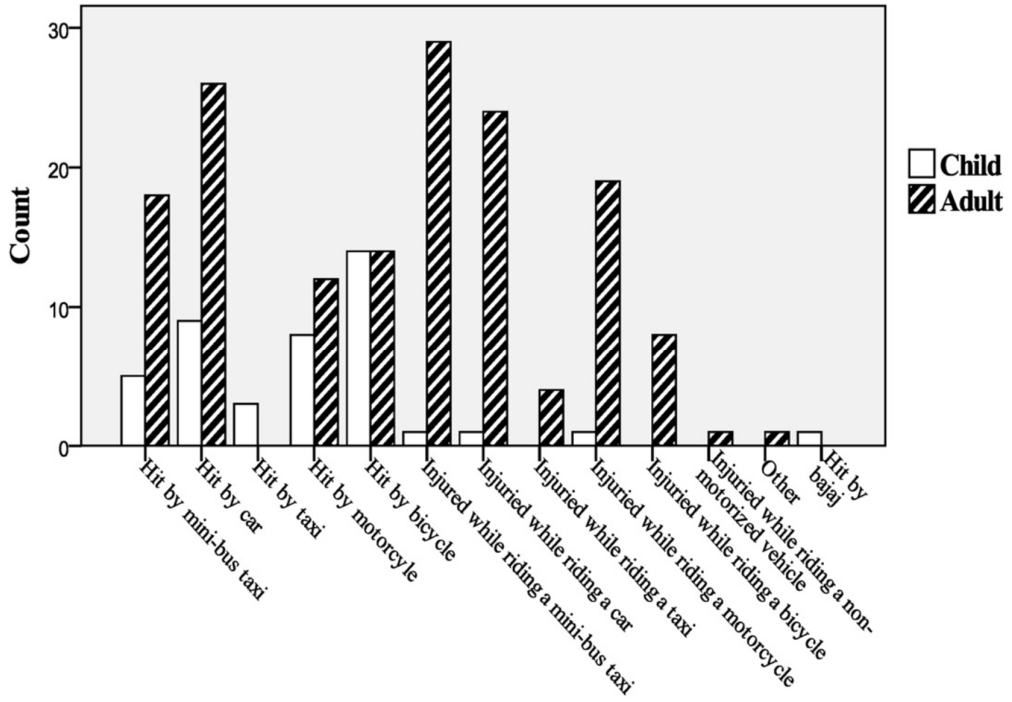
Tanzania has been chosen as a case study as it has a high level of road traffic accidents and corresponding fatalities and serious injuries. The case study has drawn upon the considerable research undertaken in Tanzania by Amend, a non-governmental organisation with an office in Tanzania. It has run programs in more than a dozen countries in the developing world at any given time, with a focus on sub-Saharan Africa. It has the goal of decreasing road traffic injury rates through advocacy, education, social marketing, and scientific research in Africa. Amend has funded several studies in Tanzania and has extensive local knowledge of road safety issues and the subsequent impact on the community, and has provided valuable information for constructing prevention measures and informing the road safety modelling.

Review of Studies in Tanzania

One of these studies by Zimmerman, Mzige et al. (2012) was undertaken in the Azimio and Mtoni wards of Dar es Salaam, the largest city and commercial capital of Tanzania. The two wards are adjacent to each other and have a single common highway bisecting them and were therefore treated as a single geographic area. This area was chosen because of anecdotal evidence of high road traffic injury (RTI) rates. Figure 1 shows the types and counts of accidents between different modes obtained from a survey in 2012.

It shows the collision type for each RTI in the study area, with the age categories divided into children (ages 0–14) and adults (ages > 14). Bicycle-related injuries were found to be the same in both the child and adult groups, comprising 13.3% of all RTIs, whereas all other categories varied significantly. Mini-bus taxis were implicated in the case of adults 30.5% of the time, though only 14.3% of the time in children. Private motor vehicles comprised 30.1% of injuries, with similar trends in both children and adults being struck by a motor vehicle.

Figure 1: Accident types in Dar es Salaam (Zimmerman, Mzige et al. 2012 p7)



The figures for children 14 years and younger are inconsistent with those from the Global Burden of Disease dataset for Tanzania. This is especially the case for injuries while riding a bicycle. The percentage of fatalities and serious injuries for the different modes for 10-14 year old males and females for all of Tanzania in 2012 is found in Table 7 and Table 8. As these tables show, GBD data suggest fatalities are mostly pedestrians or motor vehicle occupants, whereas over half of injuries occur to cyclists.

Table 7: GBD fatalities by modes Tanzania 10 to 14 cohort, 2012

Gender	Pedestrian	Cyclist	Motor cyclist	Motor vehicle	Other
Male	41.3%	6.6%	7.6%	44.3%	0.20%
Female	41.95%	4.5%	6.5%	45.4%	1.8%

Table 8: GBD injury percentages by modes Tanzania 10 to 14 cohort, 2012

Gender	Pedestrian	Cyclist	Motor cyclist	Motor vehicle	Other
Male	15.8%	61.0%	6.1%	14.6%	2.4%
Female	18.7%	56.1%	4.1%	17.5%	3.6%

For the purposes of this case study, GBD data has been used, as it has been disaggregated into males and females, as well as 10–14, 15–19 and 20–24 age cohorts. However, the study by Zimmerman, Mzige et al. (2012) did examine the severity of injuries, defined by days of school or work missed. Some 74.0% of individuals with injuries missed at least 1 day of normal activity, whereas 5.6% expected to never be able to return to work or school as a result of the RTI (Zimmerman, Mzige et al. 2012). This definition is consistent with the definition used in this report and is higher than the figure used in our previous model of 4.1% obtained from Bureau of Infrastructure, Transport and Regional Economics (BITRE) (BITRE 2009). Consequently, the higher figure from the Zimmerman et al. study is used in the Road Safety Intervention Model (RSIM) for Tanzania, as it is expected permanent serious injuries will be higher in low-income countries due to numerous factors including less advanced medical care.

The overall rate of involvement in a road traffic accident in Tanzania is 33 per 1,000 person years (as opposed to death or injury rate), emphasising the scale of road traffic accidents. However, this figure is substantially higher than other studies in sub Saharan Africa (Asogwa 1992, Andrews, Kobusingye et al. 1999, Mock, Abantanga et al. 1999). When a similar definition of RTI was used in the Zimmerman, Mzige et al. (2012) study and applied, the incidence rate dropped to 24.2 per 1,000 person years. This compares with a 2009 study from Nigeria that found the RTI incidence rate to be 41.2 per 1,000 that is significantly higher (Labinjo, Juillard et al. 2009).

The Zimmerman, Mzige et al. (2012) found individuals injured as a pedestrian represented over half of all the injuries. This figure is influenced by the high pedestrian mode share, as well as numerous factors including high speeds, alcohol, and unsafe infrastructure for pedestrians. Zimmerman et al. found children were most likely to be injured as pedestrians, often on small unpaved side streets. In a different study which focused on perceived vulnerability to RTIs, Åstrøm, Moshiro et al. (2006) found that 78% of the people included in their study in Dar es Salaam perceived being injured as a pedestrian likely or very likely. However, another study based on hospital data study done by Museru, Leshabari et al. (2002) was much more fatalistic and found that 67.8% of parents believed that “accidents were unpreventable” and many respondents quoted the Swahili saying of “ajali haina kinga”, which makes fate the determining factor for RTIs. The Museru et al. study shows pedestrians are particularly vulnerable to RTIs, and given 93% of children were involved in an RTI as a pedestrian, a program focusing on pedestrian safety for young people is of the highest importance (Zimmerman, Mzige et al. 2012).

Infrastructure

The International Road Assessment Program (iRAP) has assessed Tanzania’s road infrastructure according to both distance of roads and the travel on those roads in four different modes: motor vehicles, motorcyclist, cyclist and pedestrian. The results are shown in Table 9 and Table 10. This assessment shows most travel for motor vehicle occupants, motor cyclists and pedestrians is on 1- and 2-star roads, with some 3-star roads where cyclists overwhelmingly travel.

Table 9: IRAP star rating of roads in Tanzania, % of travel

	1-star	2-star	3-star	4-star	5-star
Motor vehicle	51.1%	26.8%	21.6%	0.5%	0.0%
Motor cyclist	52.8%	37.0%	10.2%	0.0%	0.0%
Cyclist	71.6%	22.1%	6.2%	0.0%	0.0%
Pedestrian	42.6%	54.2%	3.1%	0.0%	0.0%

Table 10: IRAP star rating of roads in Tanzania, % of road length

	1-star	2-star	3-star	4-star	5-star
Motor vehicle	62.0%	25.2%	12.6%	0.2%	0.0%
Motor cyclist	71.9%	21.1%	7.0%	0.0%	0.0%
Cyclist	69.6%	22.8%	7.5%	0.0%	0.0%
Pedestrian	41.2%	51.4%	7.3%	0.0%	0.0%

Infrastructure interventions in Tanzania

Poswayo, Kalolo et al. (2019) undertook a study investigating road safety in school areas (School Area Road Safety Assessment and Improvements – SARSAI), as well as the impacts of infrastructure interventions. Household surveys were conducted in catchment areas around 18 primary schools in Dar es Salaam. The catchment areas were divided into control and intervention groups. The data collected included demographic information on all school-aged household members, and whether or not they had been involved in an RTI in the previous 12 months. If an individual was involved in an RTI, details of that RTI were recorded. Following analysis of these surveys, road safety engineering site analysis and consultation with the local communities and other stakeholders, an injury-prevention programme was developed and implemented, consisting of infrastructure enhancements and a site-specific educational programme aimed at school-aged children. The focus on children is particularly important as children are not “little adults”. Their different anatomical structure, maturity, variety of interests, and the need for fun and safe passage to school means that children require specific interventions (Goniewicz, Goniewicz et al. 2017, Poswayo, Kalolo et al. 2019).

The programme was initially implemented at the intervention schools. After 1 year, data was collected in the same manner. The control group received the same intervention after follow-up data were collected. The SARSAI programme focused on reducing RTI among primary school student populations in urban Africa, where children are known to be at increased risk of injury via the provision of relatively inexpensive infrastructure measures that can be rapidly installed, as well as accompanying education that can be delivered quickly and inexpensively (Table 11).

Table 11: SARSAI infrastructure interventions

Infrastructure enhancement	Total number (at nine intervention schools)
Asphalt concrete speed bumps	6
Asphalt concrete rumble strips	12
Road signs	44
Thermoplastic zebra crossings	10
Thermoplastic checkerboards on speed bumps	11
Cement concrete bollards	37
Natural earth speed bumps	10
Cement concrete slabs	11

Baseline data was collected on 12,957 school-aged children and 13,555 school-aged children in the post-intervention period, in both the control and intervention communities. There was a statistically

significant reduction in RTIs in the intervention group and a non-significant increase in RTI in the control group. The greatest reduction was in motorcycle-pedestrian RTI, private vehicle-pedestrian RTI and morning RTI on their way to school (Poswayo, Kalolo et al. 2019).

The purpose of the Poswayo, Kalolo et al. (2019) study was to evaluate improvements in infrastructure and education aimed at reducing RTI among school-aged children in Dar es Salaam, while establishing characteristics (e.g. collision type) of the RTIs in this setting. The intervention group demonstrated a reduction of RTIs from pedestrians struck by private cars, school-aged children going to/from school, and overall during the morning. Speed survey data from various SARSAI infrastructure interventions are summarised in Table 12. The speed reductions from the projects that include speed humps, pedestrian footpaths and refuge islands are broadly consistent with the casualty reduction figures used by iRAP in their road safety toolkit to calculate casualty reductions (iRAP 2021a) (Table 13).

Table 12: Summary on improved infrastructure, speed surveys

Date of event (launch of improvements)	Country and city	Name of school	Speed surveys					
			Average speed			85th percentile speed		
			Before implementation	After implementation	% change from baseline	Before implementation	After implementation	% change from baseline
Year 2017								
18 March 2017	Tanzania (Dar es Salaam)	Mpakani Primary School	26km/h	20km/h	–22%	35km/h	24km/h	–31%
30 March 2017	Ghana (Accra)	Richard Akwei Primary School	24km/h	19km/h	–24%	33km/h	24km/h	–25%
18 May 2017	Côte D'Ivoire (Abidjan)	33 schools	Not applicable+	Not applicable+	Not applicable+	Not applicable+	Not applicable+	Not applicable+
24 May 2017	Benin (Cotonou)	17 schools	Not applicable+	Not applicable+	Not applicable+	Not applicable+	Not applicable+	Not applicable+
16 September 2017	Mozambique (Maputo)	Imaculada Primary School	32km/h	23km/h	–28%	38km/h	30 km/h	–21%
21 September 2017	Botswana (Gaborone)	Tlhabologo Primary School	37km/h	21km/h	–43%	45km/h	27km/h	–40%
28 September 2017	Zambia (Lusaka)	Vera Chiluba Primary School	Not available*	12km/h	Not available*	Not available*	13km/h	Not available*
19 October 2017	Namibia (Windhoek)	Moses Van der Byl Primary School	Not available*	21km/h	Not available*	Not available*	28km/h	Not available*
24 November 2017	Malawi (Lilongwe)	Kawale 1 Primary School						
30th November 2017	Senegal (Dakar)	Oumar Hamet Wane Primary School	Not available*	10km/h	Not available*	Not available*	14km/h	Not available*
Year 2018								
20 March 2018	Tanzania (Dar es Salaam)	Mikumi & Mzimuni Primary Schools	30 km/h	23km/h	–23%	37km/h	29km/h	–22%
19 May 2018	Mozambique (Maputo)	Unidade 18 Primary School	19km/h	17km/h	–11%	22km/h	21km/h	–5%

5 July 2018	Ghana (Accra)	Ayalolo Cluster of Schools and SDA school	19km/h	19km/h	0%	26km/h	25km/h	–5%
6 November 2018	Côte D'Ivoire (Abidjan)	Groupe Scolaire Vridi Canal	32km/hr	22km/hr	–31%	39km/hr	27km/hr	–31%
Year 2019								
29 May 2019	Senegal (Dakar)	École Derkle 3	12km/hr	12km/hr	0%	16km/hr	16km/hr	0%
14 June 2019	Botswana (Gaborone)	Diphetogo Primary School	27km/hr	21km/hr	–22%	35km/hr	27km/hr	–23%
4 October 2019	Malawi (Lilongwe)	Biwi Primary School	28km/hr	18km/hr	–35%	37km/hr	23km/hr	–38%
24 October 2019	Namibia (Windhoek)	Al Steenkamp Primary School	24km/hr	23.5%	–2%	33km/hr	31km/hr	–8%
29 November 2019	Zambia (Lusaka)	Kanyama Central Primary School	19km/hr	12km/hr	–37%	25km/hr	18km/hr	–28%
Year 2020								
12 March 2020	Ghana (Accra)	Oblogo Cluster of Schools	37km/hr#	32km/hr#	–14%	47km/hr#	34km/hr#	–28%
13 October 2020	Tanzania (Dar es Salaam)	Wailes Primary School	39km/hr	25km/hr	–36%	44km/hr	30km/hr	–32%
Weighted average speed (Jan 2017 – Oct 2020)			**27km/h**	**20km/h**	**–25%**			
Weighted average 85th percentile speed (Jan 2017 – Oct 2020)						**34km/h**	**25km/h**	**–27%**

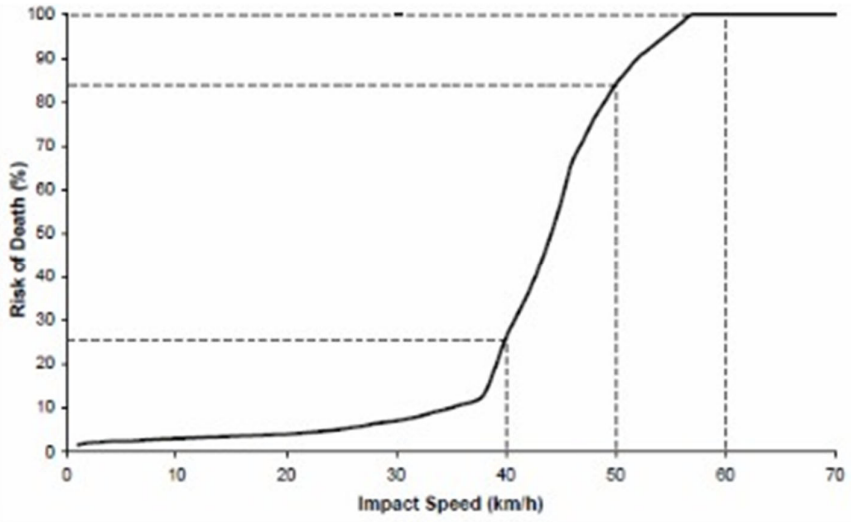
Table 13: iRAP infrastructure effectiveness ratings for pedestrians (iRAP 2021c)

Safer roads	Estimated cost	Casualty reduction
Central hatching	Low	10–25%
Pedestrian crossing – unsignalised	Low	25–40%
Pedestrian fencing	Low	25–40%
School zones	Low to medium	10–25%
Sight distance (obstruction removal)	Low to medium	25–40%
Skid resistance	Low to medium	25–40%
Pedestrian footpath	Low to medium	40–60%
Pedestrian refuge island	Low to medium	25–40%
Regulate roadside commercial activity	Low to medium	10–25%
Parking improvements	Low to medium	10–25%
Intersection – signalise	Medium	25–40%
Shoulder sealing	Medium	25–40%
Speed management	Medium	25–40%
Street lighting	Medium	10–25%
Pedestrian crossing – signalised	Medium	25–40%
Traffic calming	Medium to high	25–40%
Restrict/combine direct access points	Medium to high	25–40%
Pedestrian crossing – grade separation	High	60% or more
Service road	High	25–40%

The correlation between speeds and risk of injury shows that lower speed result in fewer casualties, as shown in Figure 2 (iRAP 2021b, iRAP 2021d). For example, the 2020 study in Dar es Salaam at Wailes Primary School showed a reduction in average speed reduced from 39km/rh to 25 km/hr, with a reduction in the risk of death from 25% to approximately 5% (Figure 2). This speed-casualty

correlation is used in iRAP's 3-star or better standard. Due to the close correlation between the survey results and iRAP's modelling, iRAP's 3-star or better infrastructure and cost modelling has been incorporated into the RSIM.

Figure 2: Speed and risk of death (Oxley 2010)



Speed

Tanzania has urban speed limits of 50km/hr with variable speed limits on rural roads and highways. In 1997, it became mandatory for all passenger vehicles to install speed 'governors' limiting the speed to 80 km/hr. However, this intervention appears to have had only a temporary or short-term effect (Museru, Leshabari et al. 2002), and does not appear to be a satisfactory long-term road safety intervention.

Safe vehicles

Tanzania has few laws with respect to safe vehicles, with no regulations regarding frontal and side impact, anti-lock braking systems, electronic stability control, seat belts and anchorage points, and no import age limit or periodic inspection. However, regulations exist with respect to import inspections.

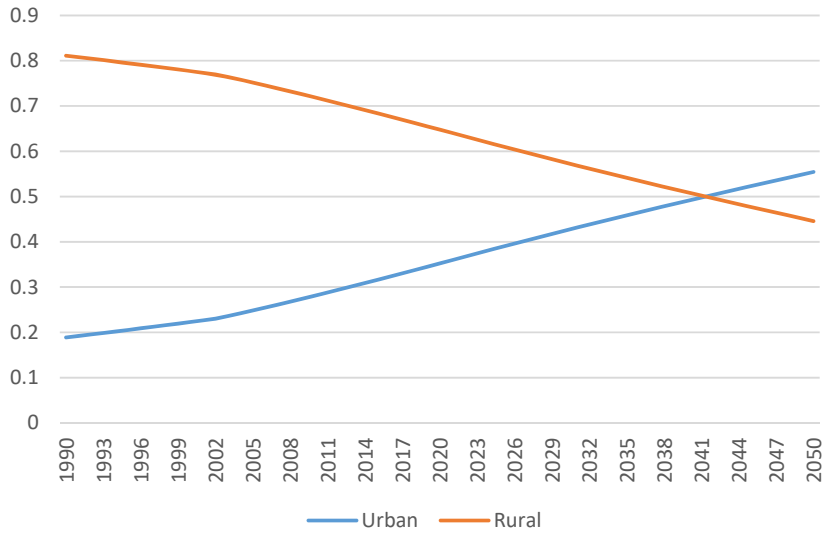
Alcohol

Tanzania has laws regarding blood alcohol limits that are set at 0.08 blood alcohol concentration (BAC). The involvement of alcohol Tanzania in RTIs has previously been found to be approximately 1% (Museru, Leshabari et al. 2002). However, anecdotal evidence suggests that drivers drink and drive with little chance of legal consequences. It is common for accident victims including drivers, passengers and pedestrians to be admitted to hospital in an intoxicated state. Dozois, Nkondora et al. (2020) report 7.8% of trauma patients registering a positive BAC. However, the Tanzanian Police have no mechanism for measuring blood/alcohol content. The few breath analysers are reportedly very underutilized and this could be a source of under reporting. This compares with Zambia, where Museru, Leshabari et al. (2002) report that 30% of drivers, pedestrians and cyclists had unacceptable levels of alcohol in the blood. These figures could represent a more accurate number than the 1% given by the Tanzanian Police (Museru, Leshabari et al. 2002). However, there is no documented evidence to support this.

Urbanisation Rate Projections

Like many countries, Tanzania is expected to become increasingly urban with a majority of the population living in urban centres by the early 2040s. This affects the rates of fatalities (generally lower) and serious injuries (generally higher). Projections for Tanzania through to 2050 using the RSIM are shown in Figure 3. As with other low and middle income countries who are experiencing high numbers of child road deaths, demographic shifts combined with ad hoc urbanisation, increasing motorisation and a lack of road safety interventions, lead to an increase in fatalities and serious injuries, despite some improvements in fatality and serious injury rates for individual modes.

Figure 3: Tanzania urbanisation projection



Population Projections

The United Nations estimated Tanzania's 2020 population at nearly 57 million, which is slightly smaller than South Africa, making it the second most populous African country located south of the Equator. Dar es Salaam, the former capital, is the country's largest city (population ~6.5 million), principal port, and leading commercial centre. In Tanzania, the 10–14, 15–19 and 20–24 age cohorts are forecast by the UN to more than double from 2020 to 2050, with both the male and female 10–14 cohort forecast to reach 7 million by 2050, 15–19 cohort approximately 6.5 million and 20–24 cohort nearly 6 million (Figure 4 and Figure 5).

Figure 4: Tanzania female population projection

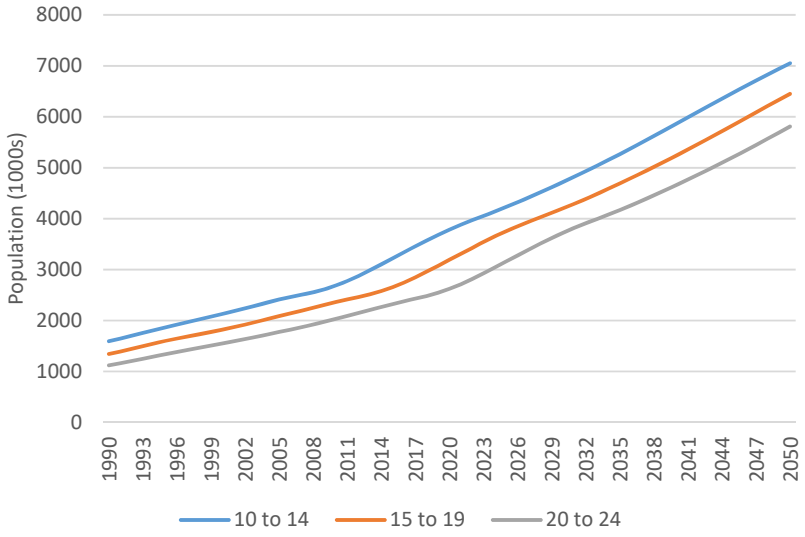
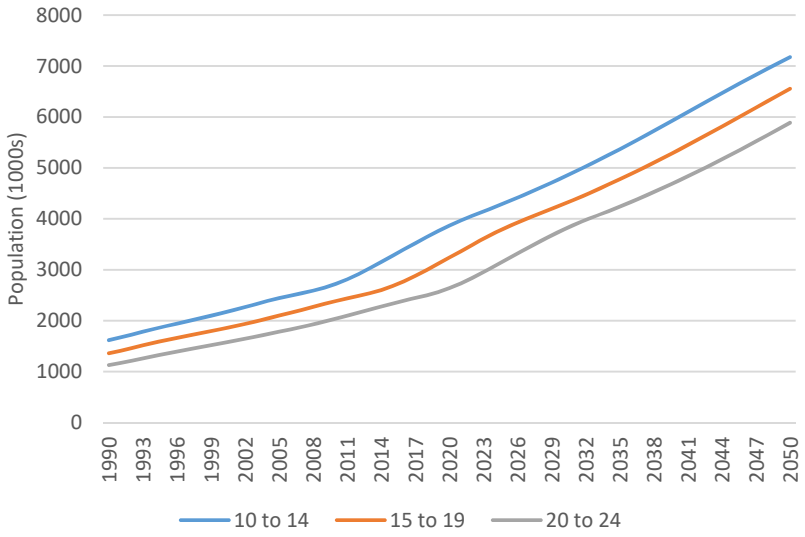


Figure 5: Tanzania male population projection



Modelling Interventions Using the Road Safety Intervention Model

We used the Road Safety Intervention Model (RSIM) to estimate the impact of a range of interventions on road traffic fatalities and injuries in Tanzania. We assume that interventions are introduced in 2022 and increase linearly over time, reaching a maximum in 2030 where they maintain that effect until 2050.

The interventions and the way they are incorporated into the model are described in the main report with the specific effectiveness for Tanzania for each intervention shown in Table 14.

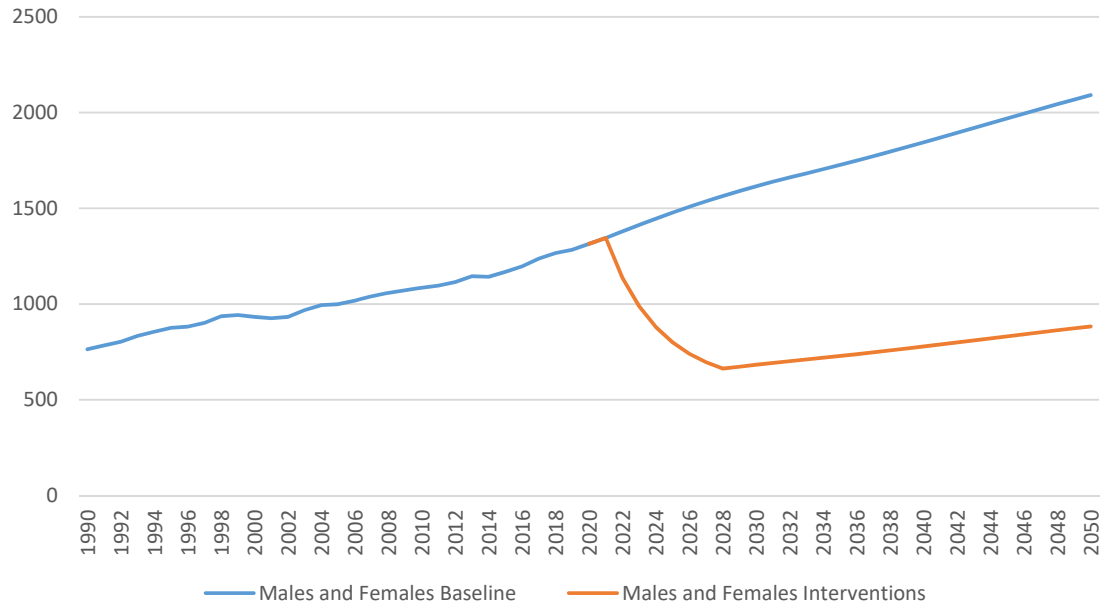
Table 14: Interventions and effectiveness

	Intervention	Effective reduction
Motor cycles	Helmets	36%
	Alcohol enforcement	5%
	Infrastructure	46%
	Speed compliance	14%
	Public awareness and education	4.5%
	Graduated licensing scheme 15–19	20%
	Graduated licensing scheme 20–24	4%
Motor vehicles	Seat belts	20%
	Alcohol enforcement	5%
	Infrastructure	39%
	Speed compliance	14%
	Graduated licensing scheme 15–19	20%
	Graduated licensing scheme 20–24	4%
	NCAP	1%
	Public awareness and education	4.5%
Cyclists	Alcohol enforcement	5%
	Infrastructure	52%
	Speed compliance	14%
	Public awareness and education	4.5%
Pedestrians	Alcohol enforcement	5%
	Infrastructure	47%
	Speed compliance	14%
	Public awareness and education	4.5%
All	Capacity building	N/A

Fatalities

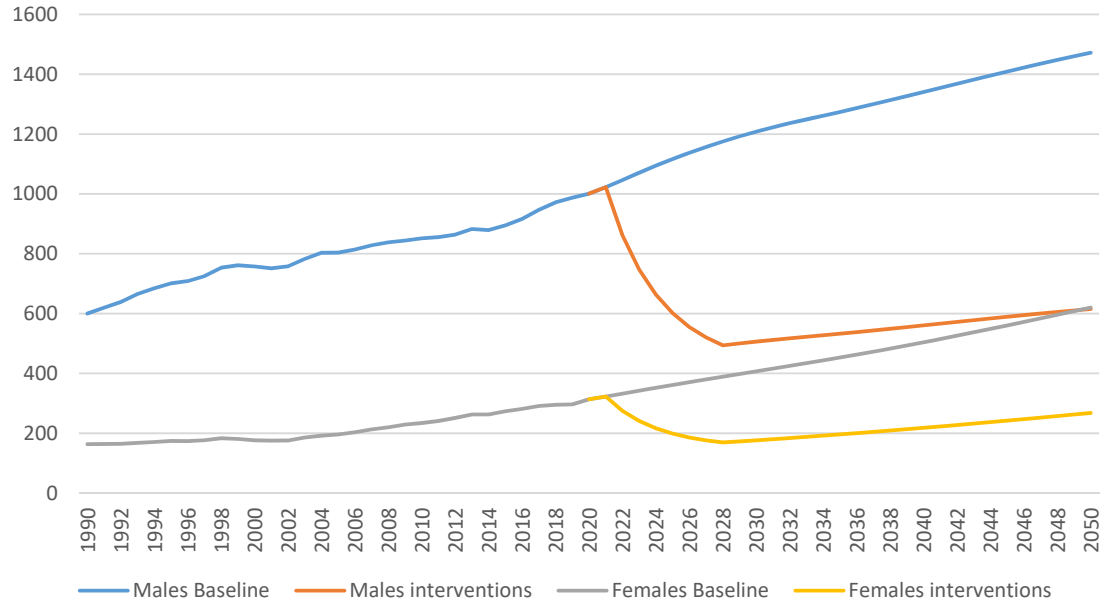
Implementation of all the interventions leads to a 59.9% reduction in the annual figure for fatalities from a projected baseline in 2030 of 1,616 to 648. Total, as well as male and female, baseline projections and all intervention projections are shown in Figure 6. The effect of the full set of interventions is dramatic with a 58% reduction in fatalities by the time they are fully implemented in 2030. Despite the dramatic reductions, once the interventions have reached full effectiveness, the number of fatalities begins to increase, this is due to the massive population growth.

Figure 6: Total baseline and intervention fatalities



The projected baseline and intervention number of male and female road traffic fatalities in Tanzania is given in Figure 7, and shows the disparity between male and female fatalities in the 10 to 24 age cohort. The difference between males and females was nearly a factor of four in 1990, a factor of 3 in 2020 and baseline projections suggest a factor of two and a half by 2050. This reducing trend between male and female fatalities reflects increasing rates of fatalities for females towards those of males.

Figure 7: Male and female baseline and intervention fatalities



Serious injuries

The projected baseline number of serious injuries for the 10 to 24 shows the incidence of serious injuries is approximately ten times that of fatalities from 1990 to 2020. After 2020, the rate of serious injuries increases relative to fatalities, so by 2050 the number of serious injuries is over sixteen times that of fatalities in the base case (Figure 8).

The incidence of male and female serious injuries for the 10 to 24 age cohort is shown in Figure 9. Male serious injuries are significantly higher than females, however, the ratio reduces from 3 in 1990, to 2.7 in 2020, to 2 in 2050. The proportion of serious injuries relative to fatalities also increases for both males and females, which is due to the increasing serious injury rates for nearly all female modes and age cohorts, but only some of the male modes. The interventions has a slightly larger effect on serious injuries compared to fatalities with a 59% reduction.

Figure 8: Total baseline and intervention serious injuries

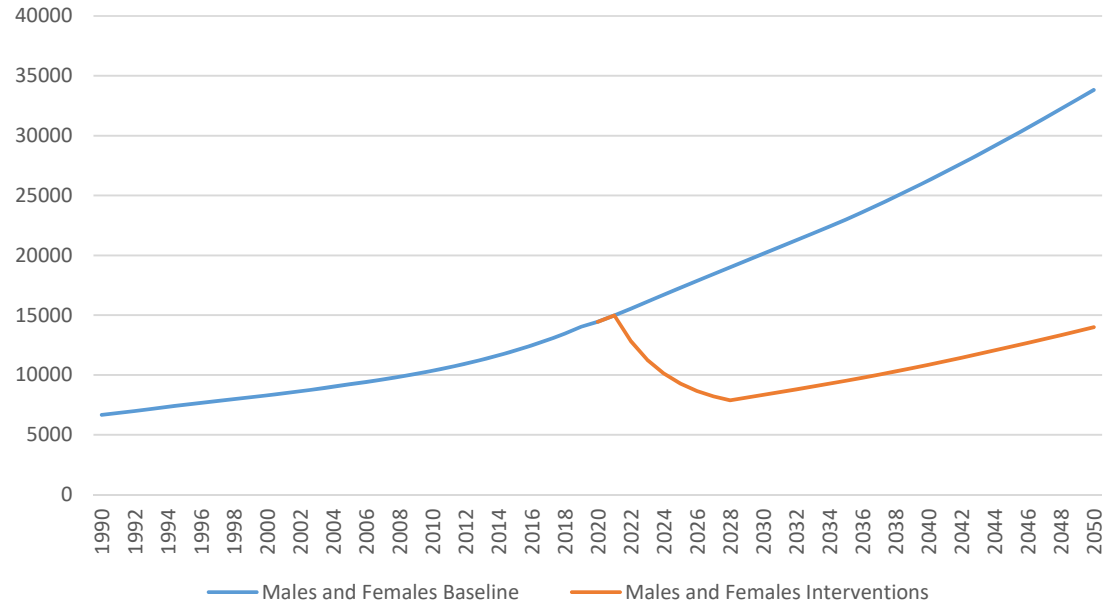
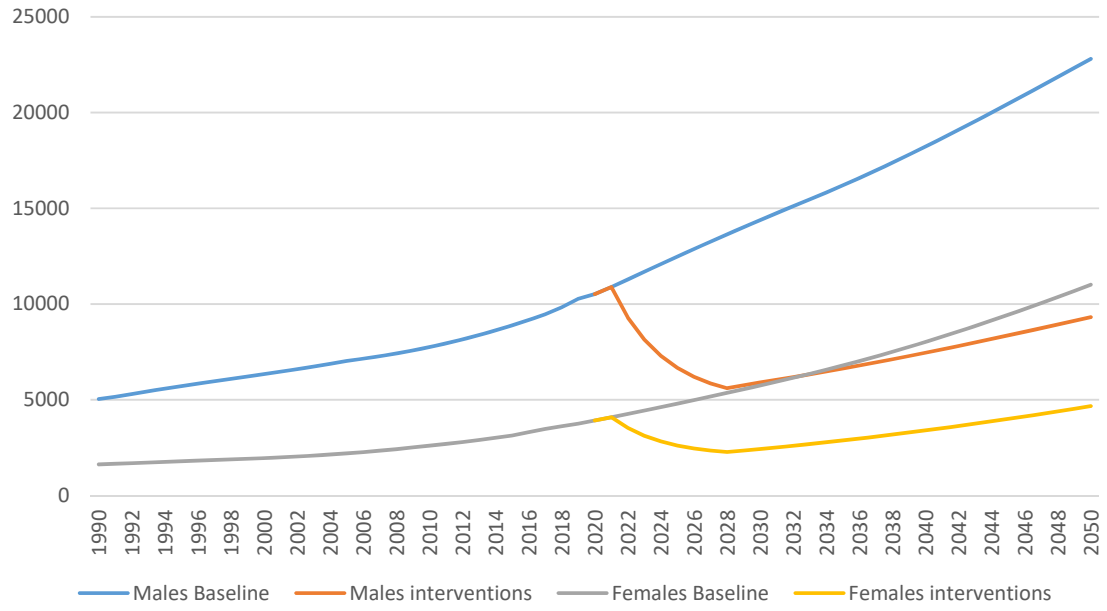


Figure 9: Male and female baseline and intervention serious injuries



10 to 14 cohort

Fatalities

The baseline total male fatalities for this age cohort shows a gradually increasing number of fatalities for both males (176 in 2019 to 205 in 2050) and females (107 in 2019 to 155 in 2050) each year, which masks gradually falling trends in fatality rates for all modes (Figure 10). The total number of female fatalities is consistently lower for females than males across all age groups, but the 10 to 14 cohort have the closest values (Figure 11). The increase in number of fatalities is due to the rapid population growth being higher than the falling fatality rates.

As expected in Tanzania where most people in this age cohort walk as the main form of transport, and consistent with evidence from surveys undertaken by Amend, pedestrian fatalities make up a considerable portion of the total fatalities. Pedestrian constitute approximately 40% for both males and females, and motor vehicle occupants also make up approximately the same amount for males but slightly more for females (~48%), with very similar figures for the other modes (cyclist and motor cyclist). The increase for females is expected to come nearly entirely from motor vehicle occupants, whereas for males the increase is evenly split between pedestrians and motor vehicle occupants. Due to pedestrians and motor vehicle occupants making up the vast majority of fatalities, interventions aimed at this modes will have the greatest effect, e.g. improved infrastructure, seat belt wearing and speed compliance.

Figure 10: Total male fatalities 10–14 cohort

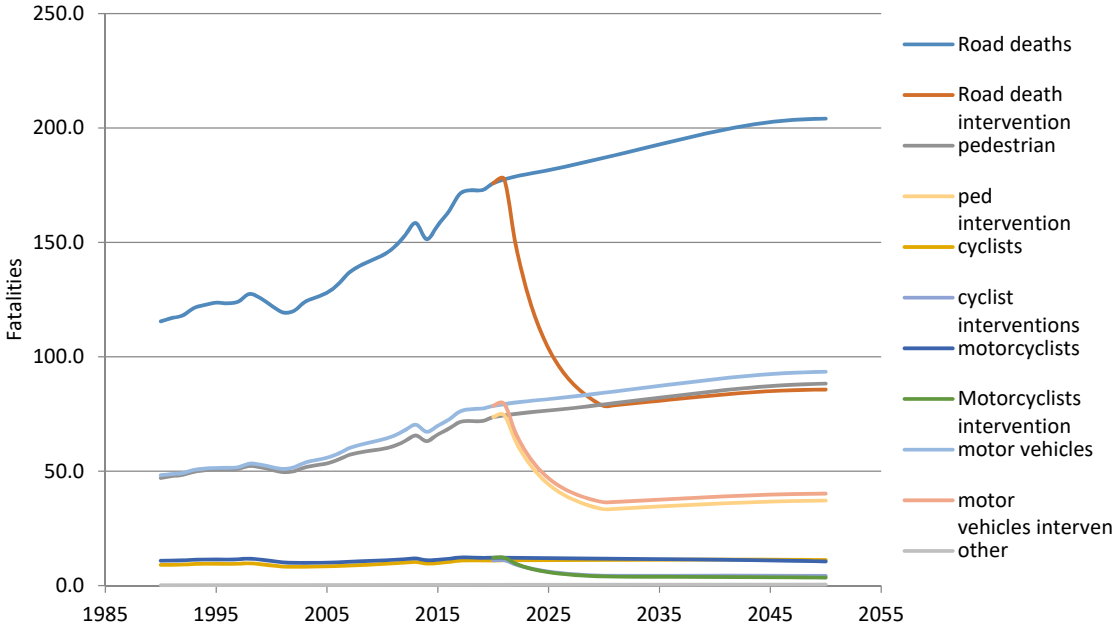
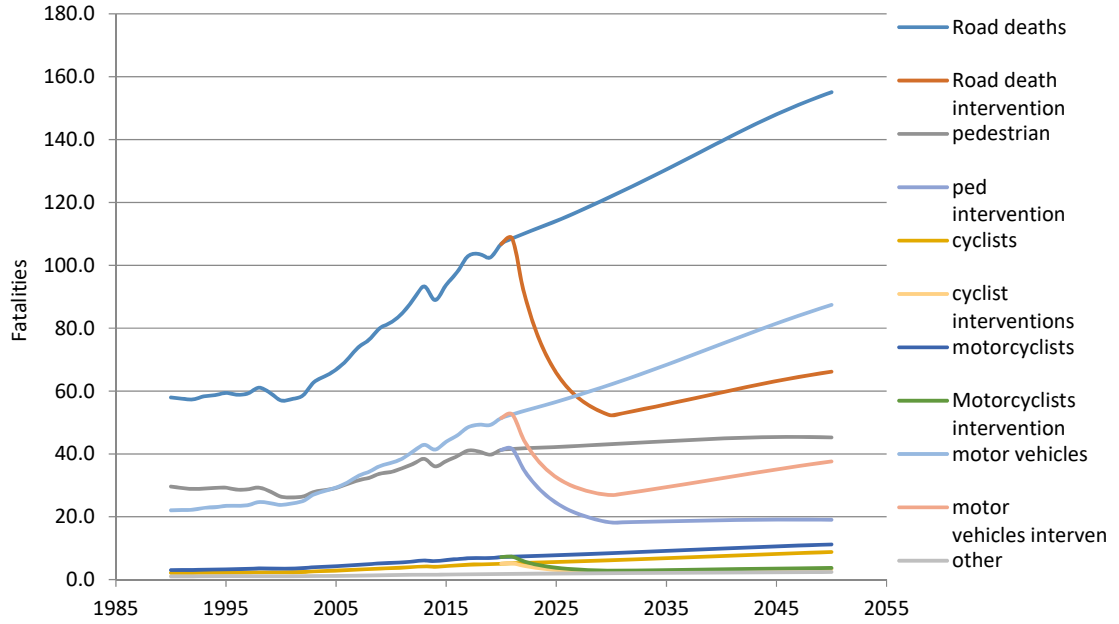


Figure 11: Total female fatalities 10–14 cohort



Urban and Rural

The increase in fatalities for both males and females is expected to mainly come in urban areas due to the increasing population and increasing urbanisation (Figure 12 and Figure 13). Consequently, rural fatalities are expected to marginally decline in the coming decades, even without additional interventions (Figure 14 and Figure 15)

Figure 12: Urban male fatalities 10–14 cohort

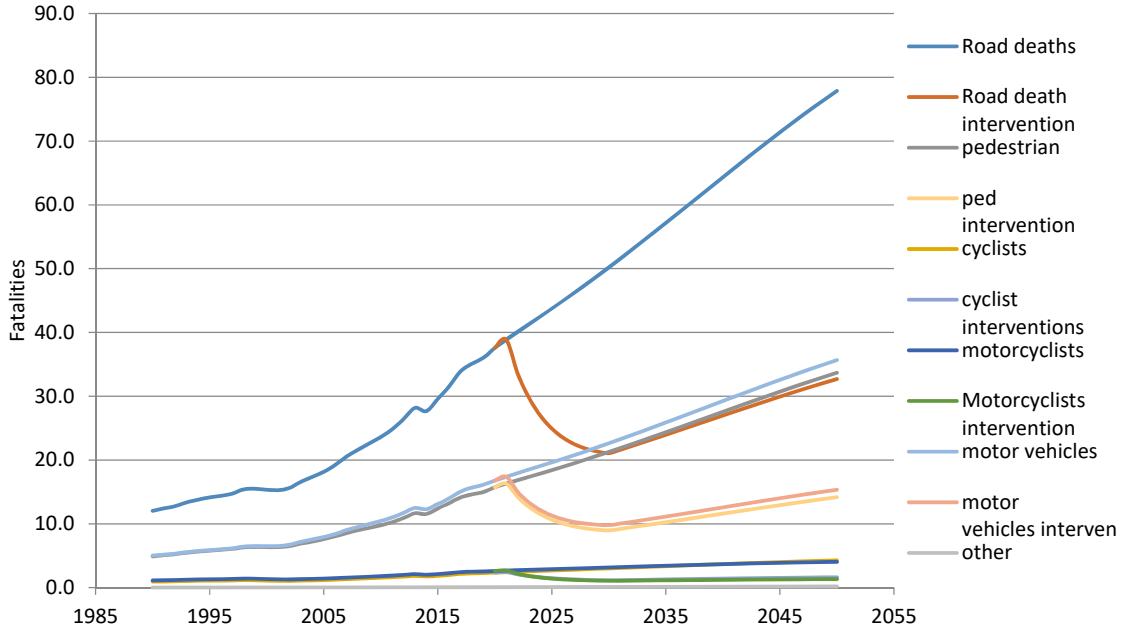


Figure 13: Urban female fatalities 10–14 cohort

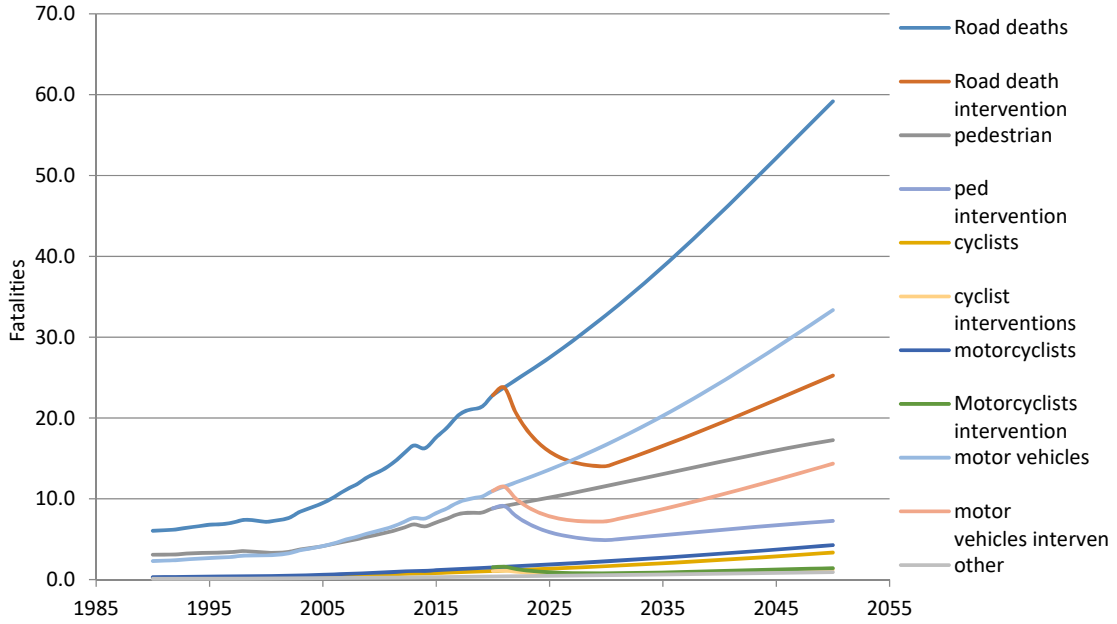


Figure 14: Rural male fatalities 10–14 cohort

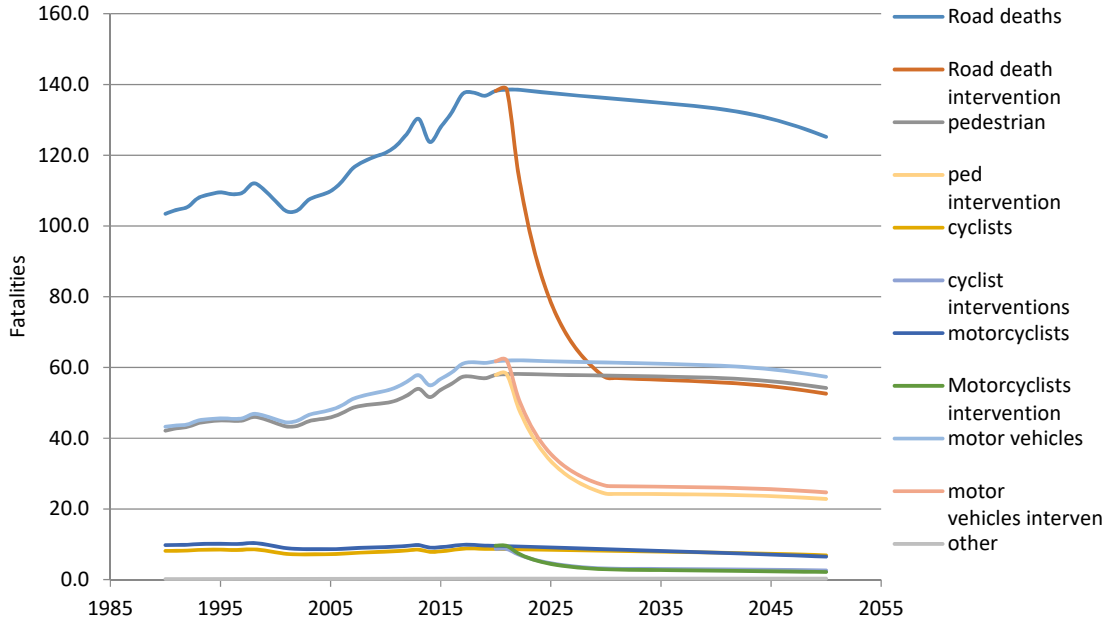
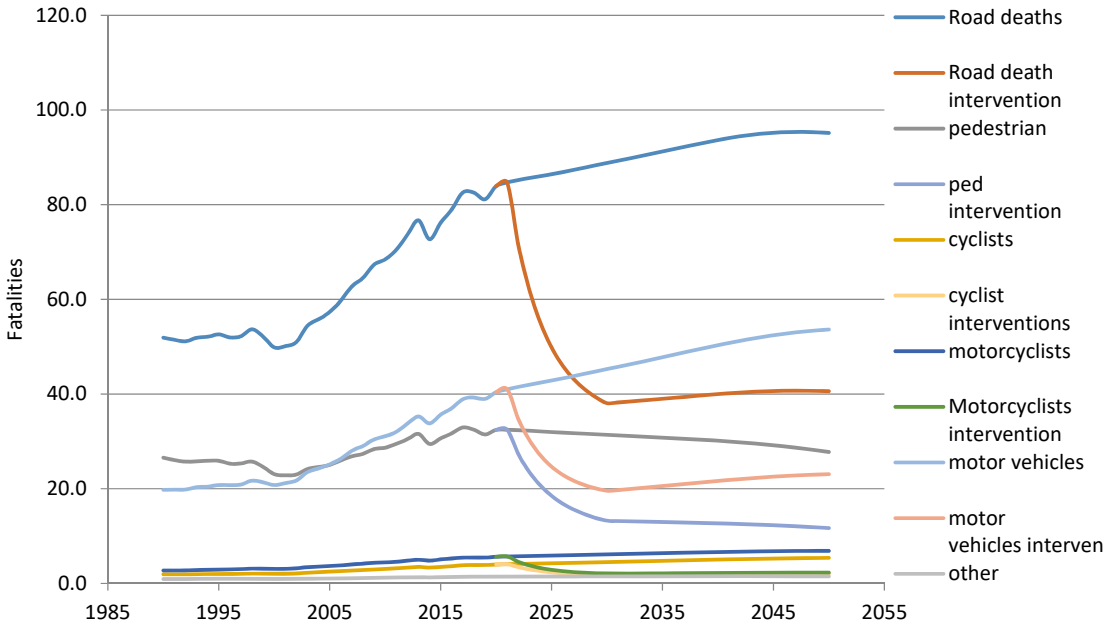


Figure 15: Rural female fatalities 10–14 cohort



Serious injuries

The pattern and composition of serious injuries is substantially different to fatalities in Tanzania. Serious injuries are expected to rapidly increase due to a combination of increasing population and increasing rates. For males, serious injuries are expected to increase from 2,430 per annum in 2019 to 5,800 in 2050 (Figure 16), while for females they are expected to increase from 1,600 to 4,000

(Figure 17). These increases are primarily due to the very high rates of serious injuries that occur to cyclists according to the GBD data. This group of serious injuries is by far the largest (approximately 60% for males and 50% for females), representing more than all the other modes combined for both males and females. The large percentage of serious injuries to cyclists would suggest interventions aimed at making cyclists safer would be the most appropriate investment, including speed and alcohol compliance, as well as better infrastructure. However, the nature of the accident type needs to be determined before this can confidently be stated. If most of the accidents involve other vehicles, e.g. motor vehicles and motor cycles, then this course of action would be most appropriate. However, if the majority of these accidents were single vehicle cycling accidents, then further research would need to be undertaken to determine the cause of these accidents. Research from the Netherlands (Schepers and Wolt 2012) suggests that about half of all single-bicycle crashes are related to infrastructure. For example, the cyclist collided with an obstacle, rode off the road, the bicycle skidded due to a slippery road surface, or the rider was unable to stabilize the bicycle or stay on the bike because of an uneven road surface. The other types of accidents included loss of control at low speed or poor or risky riding behaviour, while bicycle defects are responsible for a very small group of crashes. If the same causes hold true in Tanzania, a focus on better quality infrastructure would seem to be most appropriate.

Figure 16: Serious and permanent injury total male 10 to 14 cohort

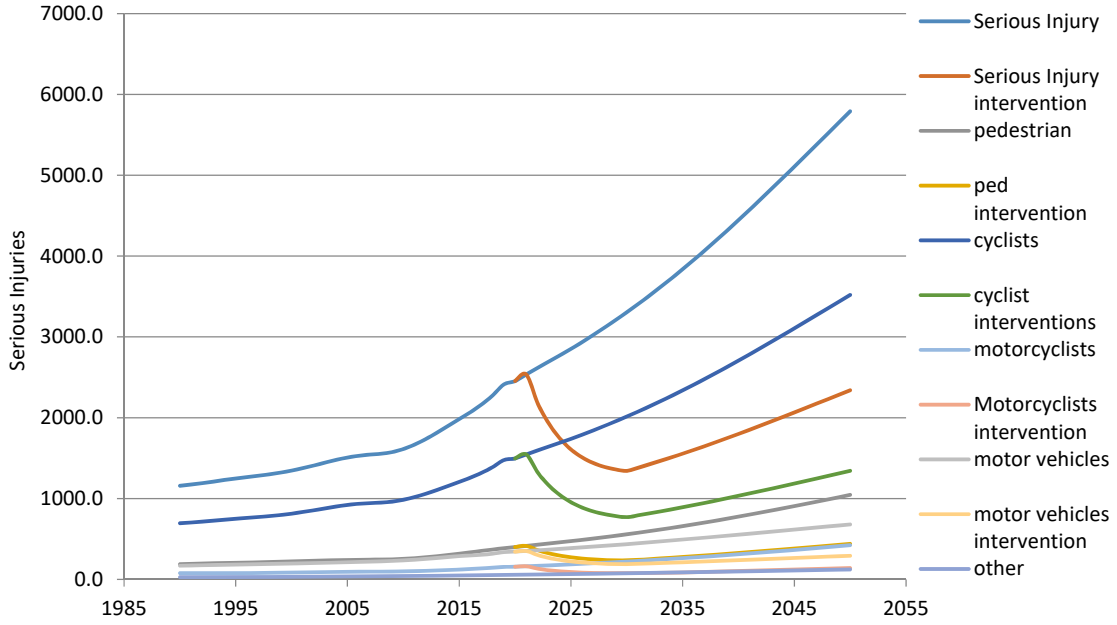
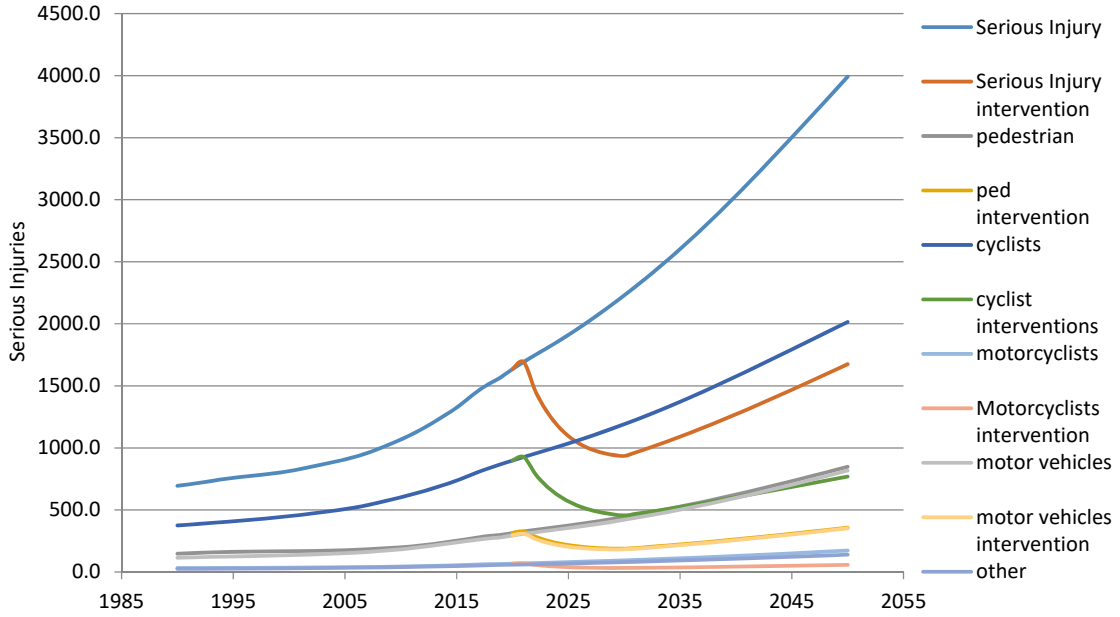


Figure 17: Serious and permanent injury total female 10 to 14 cohort



Urban and Rural

While serious injuries are expected to increase for both males and females in rural settings, the increase is not forecast to be nearly as dramatic as urban settings. In urban areas the increasing population and increasing urbanisation, combined with a tendency for accidents to more likely result in injuries in urban settings lead to rapid rises (Figure 18 and Figure 19). The injury rates for all modes for females is expected to increase, and the same is true for males except for motor vehicle occupants, however, the highly variable data suggests this may be a data quality issue. This is due to a smaller percentage of the population living in rural settings and the lower rates of serious injuries in rural settings.

Figure 18: Serious and permanent injury urban male 10 to 14 cohort

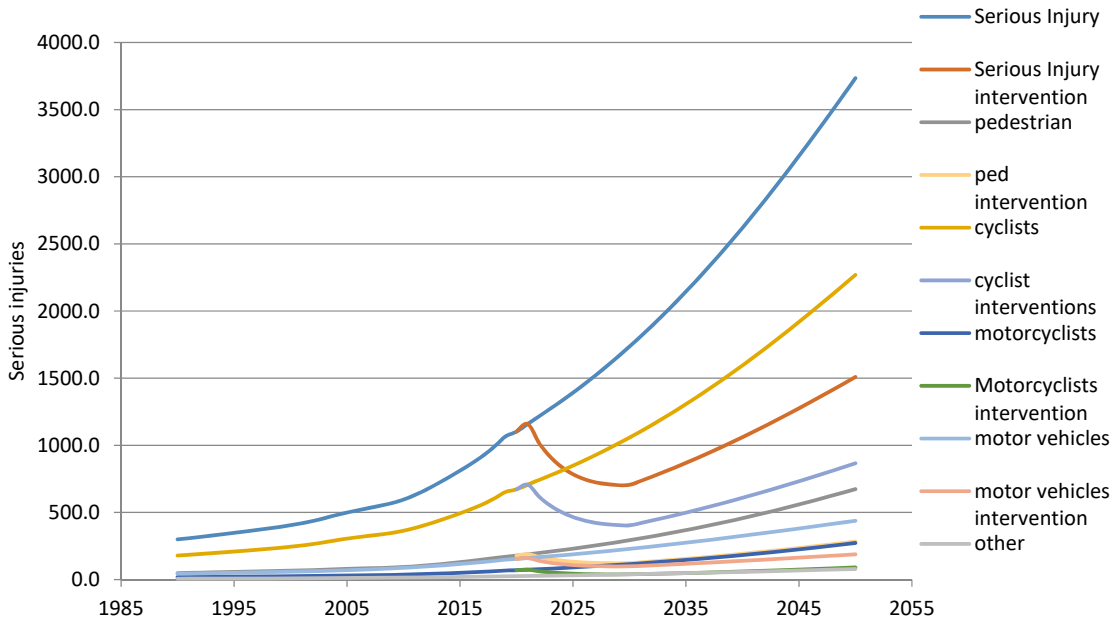


Figure 19: Serious and permanent injury urban female 10 to 14 cohort

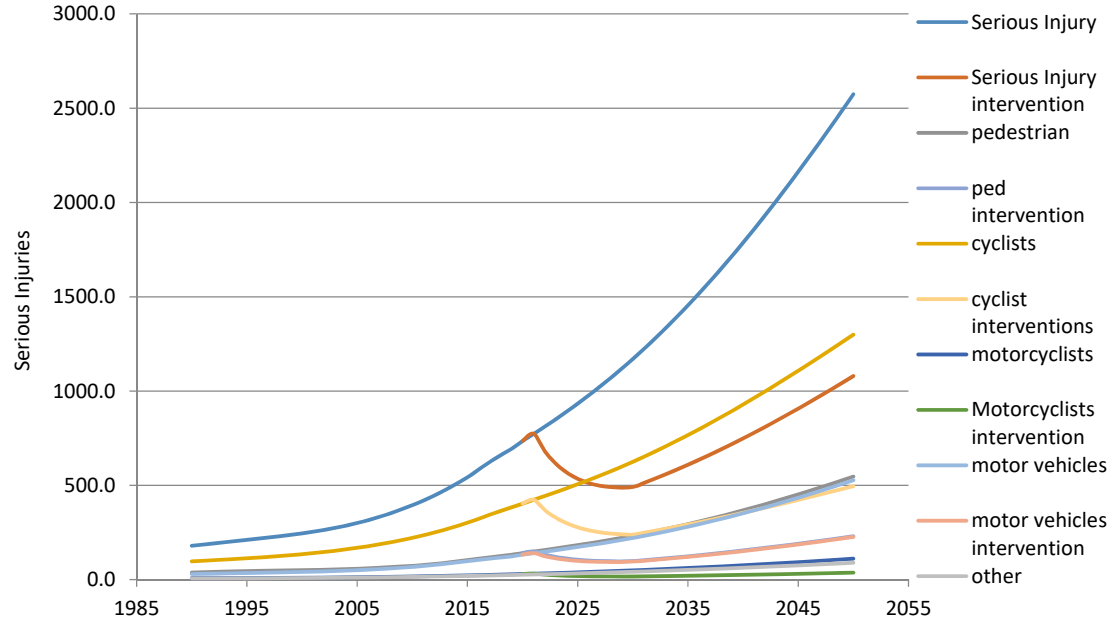


Figure 20: Serious and permanent injury rural male 10 to 14 cohort

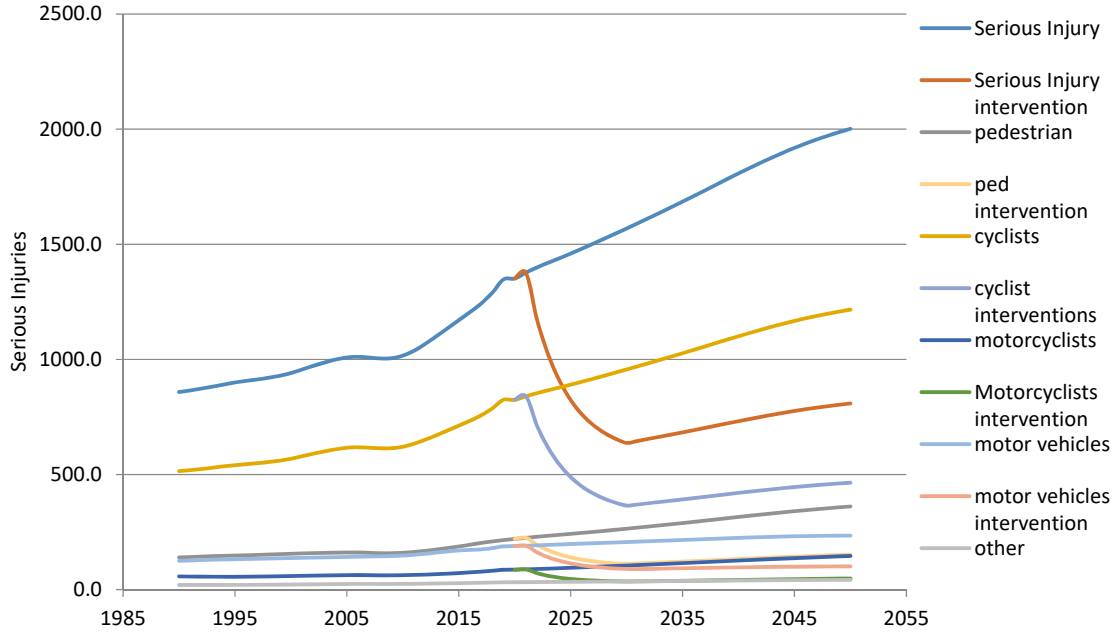
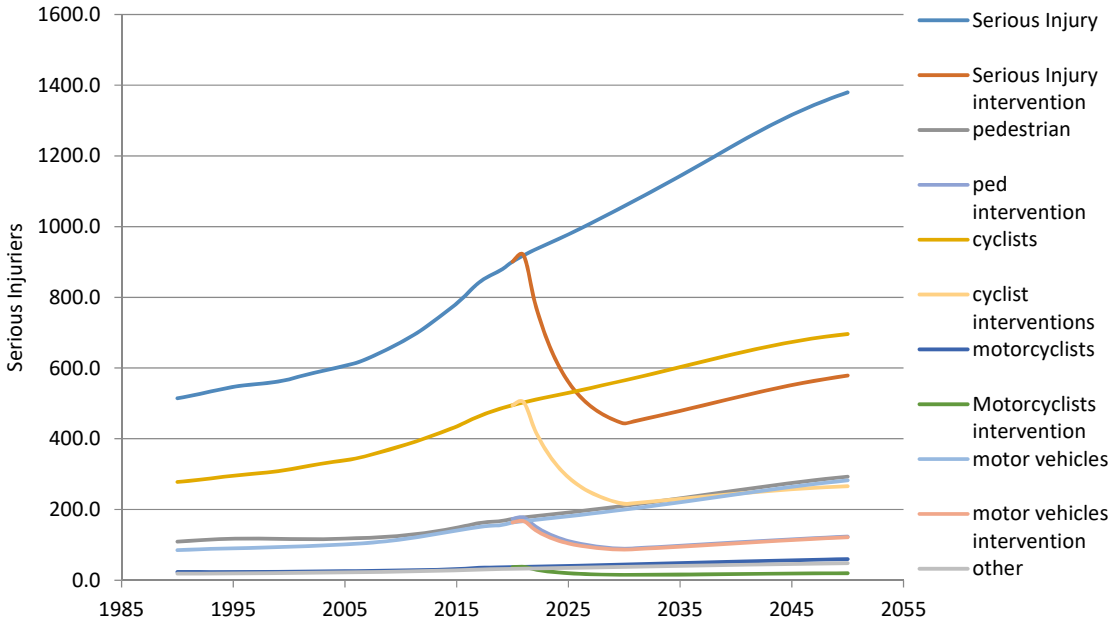


Figure 21: Serious and permanent injury rural female 10 to 14 cohort



15 to 19 cohort

Fatalities

The pattern and trend for fatalities for the 15 to 19 cohort follows a similar trend as the 10 to 14 cohort showing an increasing baseline for both and the same main causes of fatalities; namely motor vehicle occupants and pedestrians. Males have slightly more fatalities among motor vehicle occupants than pedestrians (Figure 22), and females have both a higher percentage of motor vehicle

fatalities (Figure 23), but also an increasing proportion of motor vehicle occupants due to the higher trend for motor vehicle occupants than males. For females, the trend for motor vehicle fatalities is increasing among 15 to 19 year olds, whereas for males it is gradually decreasing. The major difference between the 15 to 19 and 10 to 14 cohorts is the total number of fatalities for males that is substantially higher. In 2019, there were approximately 400 male fatalities (176 for 10 to 14 year olds), and there are forecast to be 558 fatalities in 2050 in the base case (205 for 10 to 14 year olds). For females, the values are relatively similar with 119 female fatalities in 2019 (107 for 10 to 14 year olds) and forecast to be 234 fatalities in 2050 (155 for 10 to 14 year olds). Successfully reducing the number of fatalities clearly lies in the same area as with the 10 to 14 cohort, i.e., motor vehicles and pedestrians. Consequently, interventions that focus on this area will have the greatest impact, such as speed and alcohol compliance, infrastructure and possibly a graduated licensing scheme. However, data regarding the number of 18 and 19 year olds who have a driver's license is unavailable and it is possible this figure is very low. The increasing trend of motor vehicle fatalities for females should also be the subject of further research, as this stands in stark contrast with the male cohort, who have a higher rate that is declining, as opposed to females who have a lower rate that is increasing.

Figure 22: Fatalities total male 15 to 19 cohort

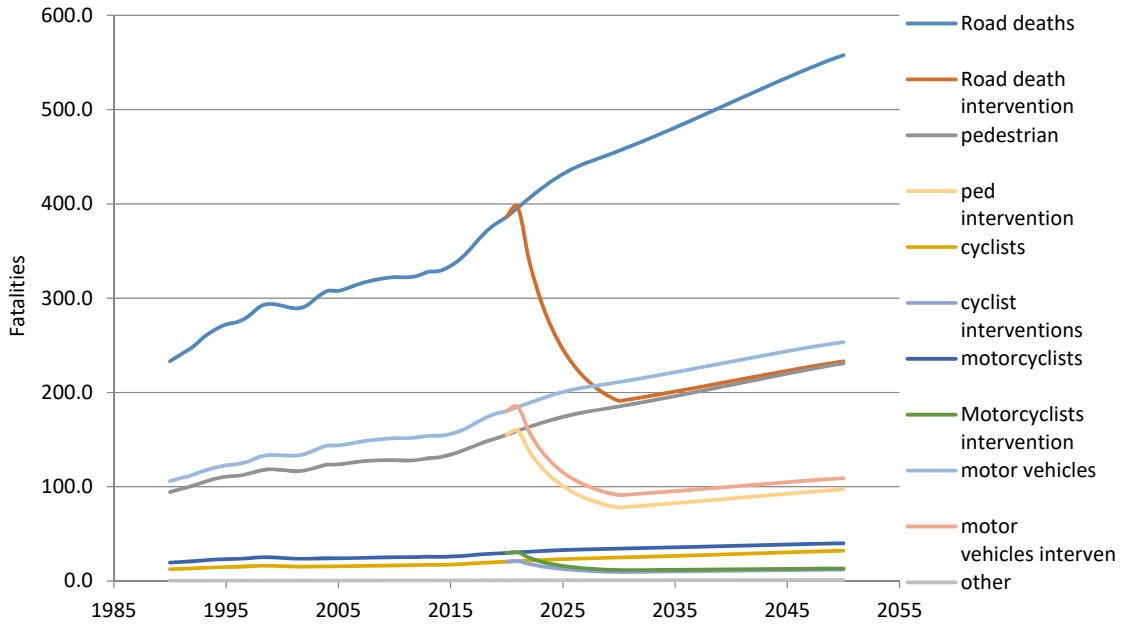
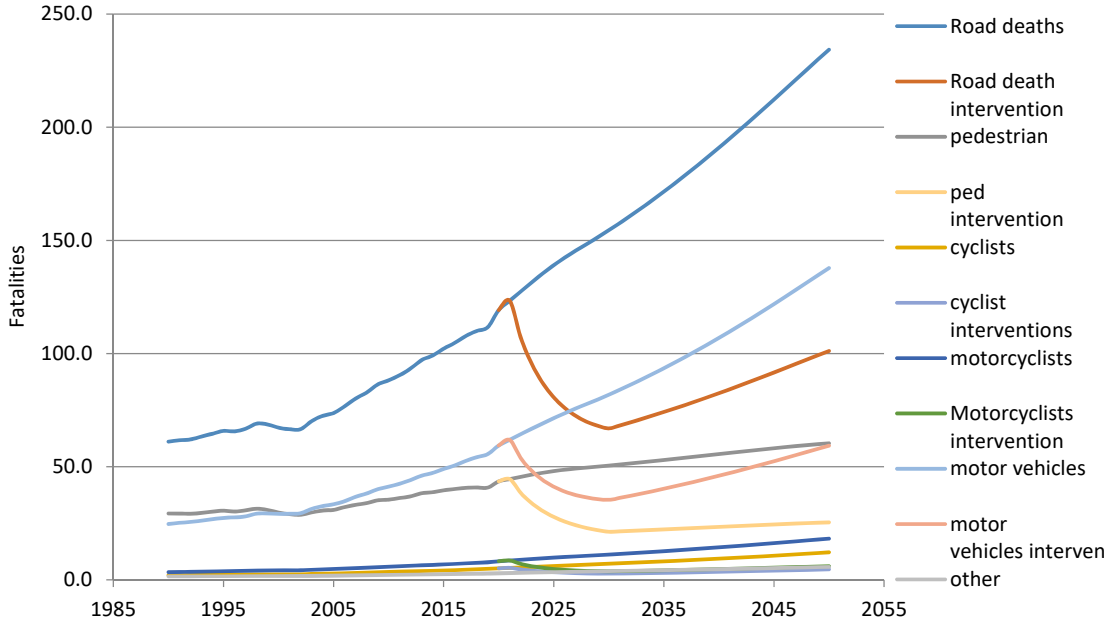


Figure 23: Fatalities total female 15 to 19 cohort



Urban and rural

Both male and female base case urban fatalities are expected to increase at a substantial rate from a relatively low base (80 for males and 25 for females in 2019 to 213 and 89 in 2050, respectively), which is mostly due to the increasing rate of urbanisation. As with the 10 to 14 cohort, motor vehicle occupants and pedestrians make up most of the fatalities for both males and females, with the proportion of motor vehicle occupant fatalities increasing over time for females (Figure 24 and Figure 25).

The rural fatalities for males are expected to plateau due to the increasing urbanisation and declining fatality rates, while increasing for females with the increase coming entirely from a growing trend in motor vehicle fatality rates (Figure 26 and Figure 27).

Figure 24: Fatalities urban male 15 to 19 cohort

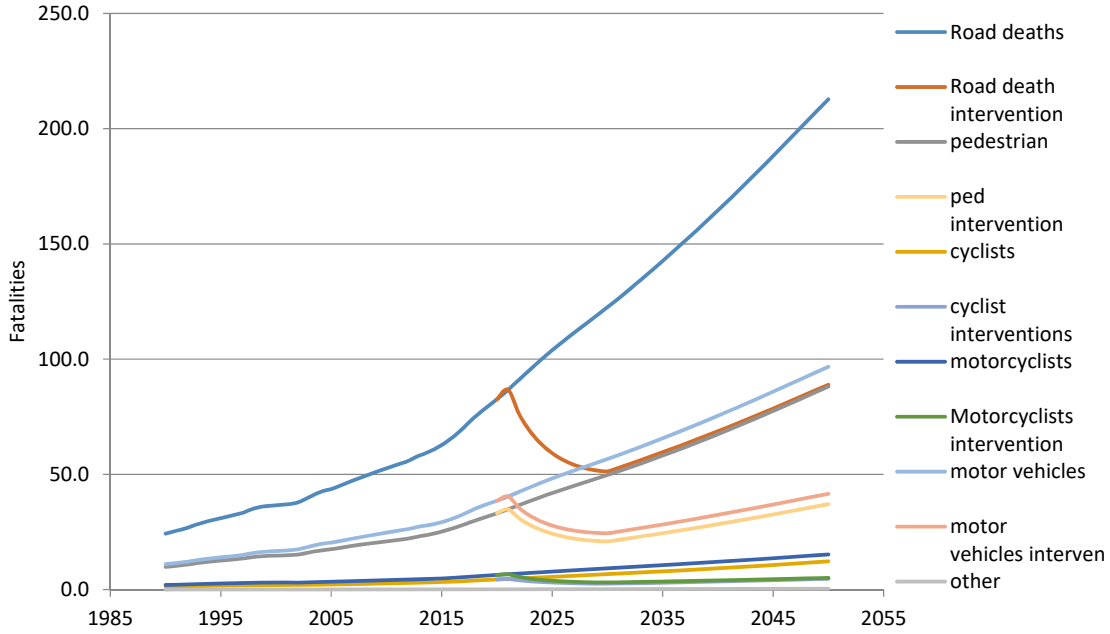


Figure 25: Fatalities urban female 15 to 19 cohort

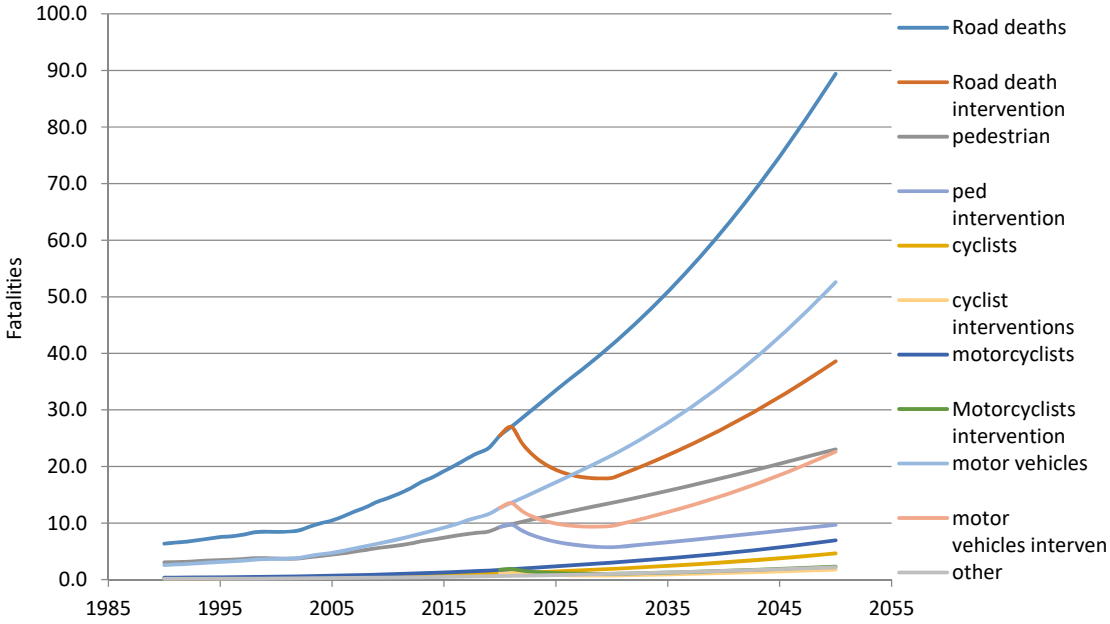


Figure 26: Fatalities rural male 15 to 19 cohort

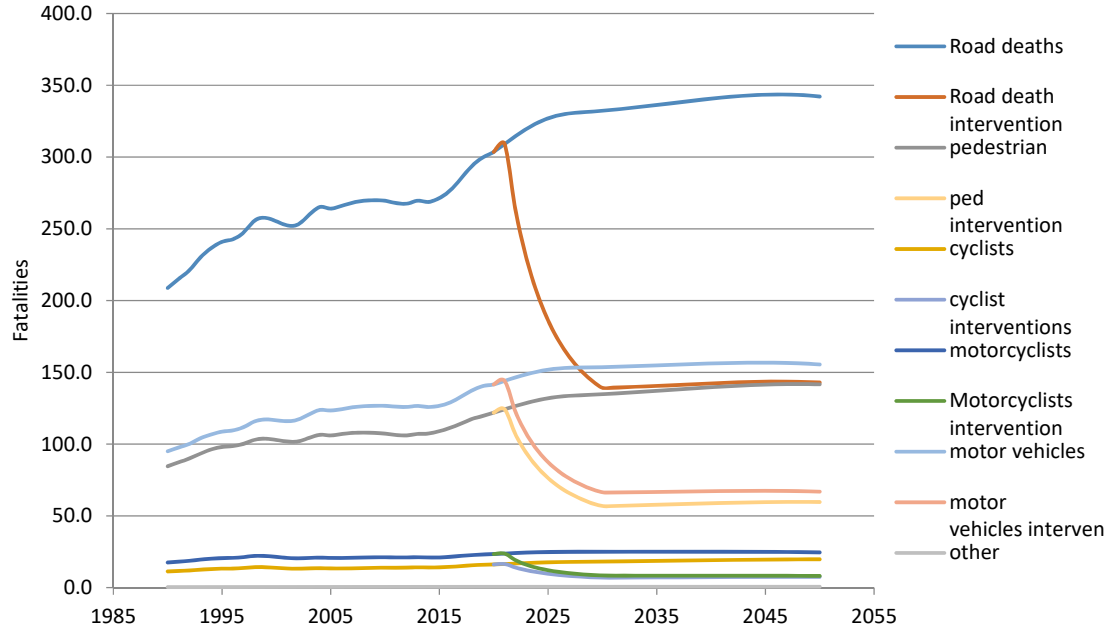
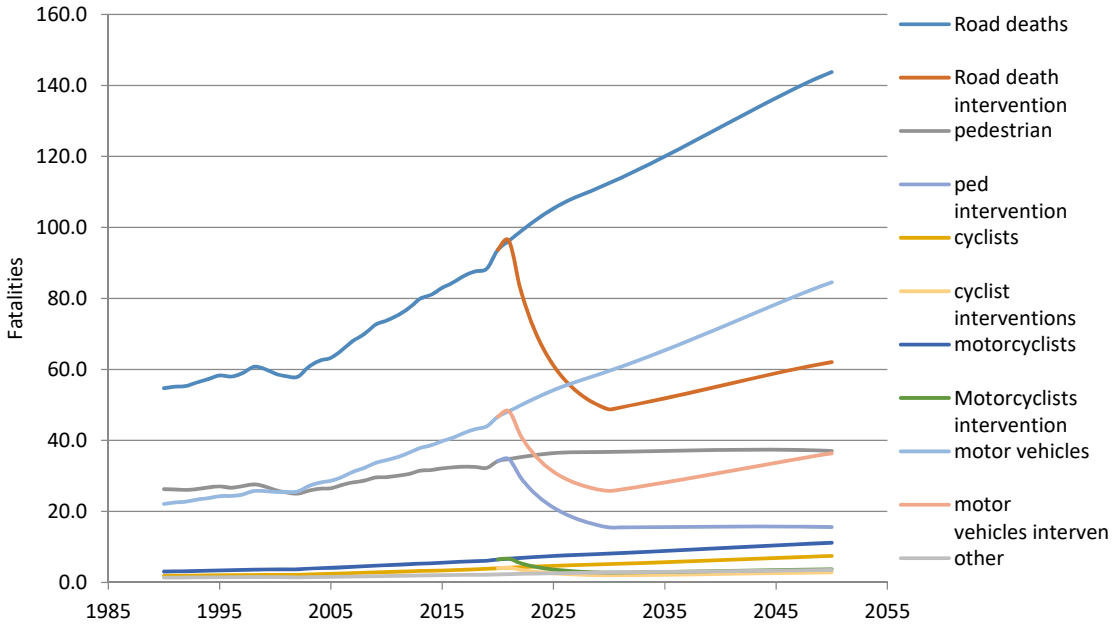


Figure 27: Fatalities rural female 15 to 19 cohort



Serious injuries

Baseline serious injuries for 15 to 19 year-old males are expected to approximately double between 2019 and 2050 from approximately 4,000 to over 8,000 per annum due to some increasing mode rates and increasing population (Figure 28). As with the 10 to 14 cohort, by far the largest number of serious injuries is expected to occur to cyclists (~51%), with pedestrians comprising 23% (Figure 29).

For males, the percentage of cyclists who have serious injuries is expected to increase to 54% by 2050. The serious injury rates for all modes are expected to increase, with the exception of motor vehicle occupants that is trending slightly lower.

For females, the number of serious injuries is expected to more than double from approximately 1,400 to over 3,700 in 2050. All individual mode rates for females increase, together with an increasing population, which leads to this dramatic increase. As with the 10 to 14 age cohort, cyclist injuries make up by far the largest proportion of all injuries for both males and females. The serious injury rate trends for all modes are increasing, which contributes to the steep increase in female serious injuries. As with the fatality rates for males and females in the 15 to 19 cohort, the difference between male and female serious injury rates for motor vehicle is an area that requires further investigation.

Figure 28: Serious and permanent injury total male 15 to 19 cohort

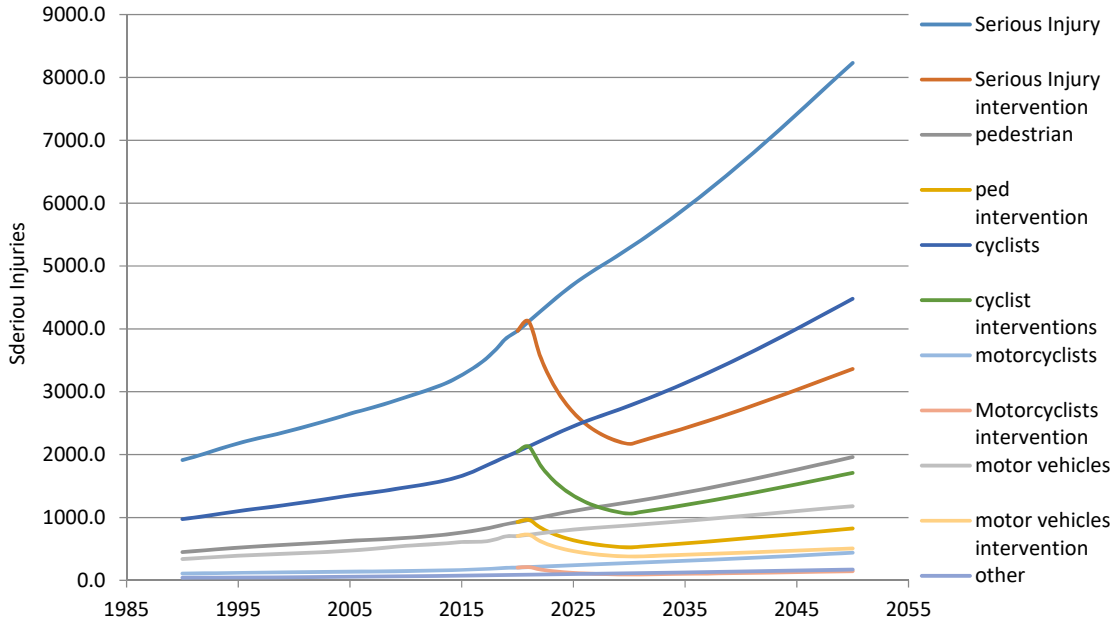
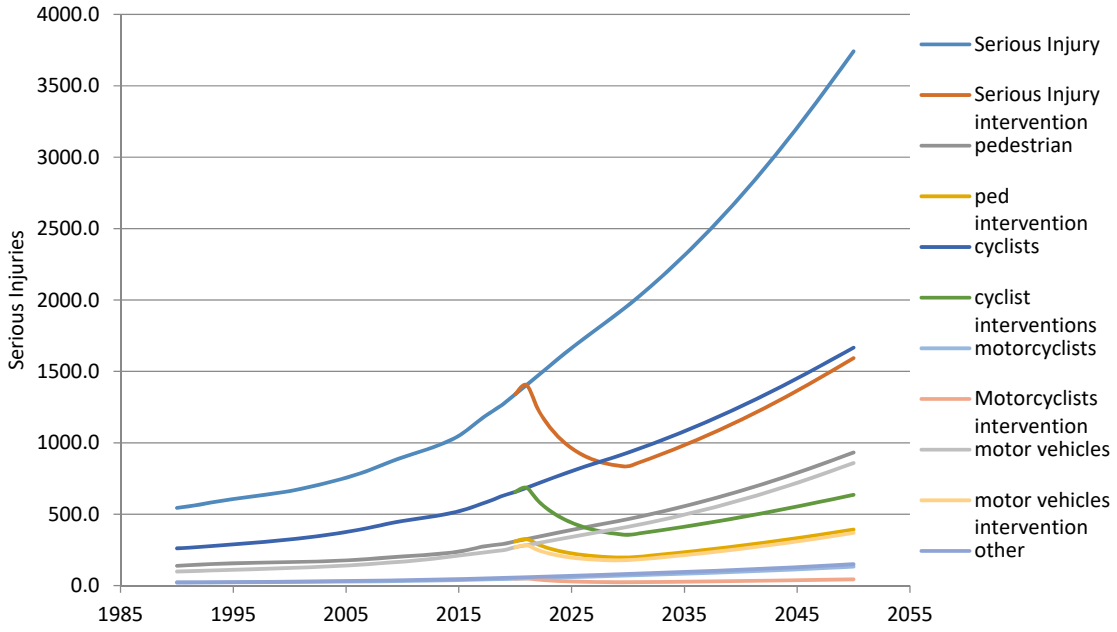


Figure 29: Serious and permanent injury total female 15 to 19 cohort



Urban and rural serious injuries

Urban serious injuries are expected to more than double for males, and that is entirely due to increased urbanisation and increased population (Figure 30). This compares with females, where the number of serious injuries increases by more than a factor of four between 2019 and 2050, with cyclist injuries making up the vast majority for both (Figure 31). The overall number of urban serious injuries is double that of rural serious injuries. Rural male serious injuries are expected to increase to a much lesser extent between 2019 and 2050 than urban serious injuries. This is primarily due to the decreasing percentage of rural population. Rural female serious injuries are expected to nearly double between 2019 and 2050, with cyclists again making up the majority of serious injuries for both males and females (Figure 32 and Figure 33). Clearly interventions to address the safety of cyclists would be most effective at addressing these serious injuries, with interventions focussing on pedestrians the next more important.

Figure 30: Serious and permanent injury urban male 15 to 19 cohort

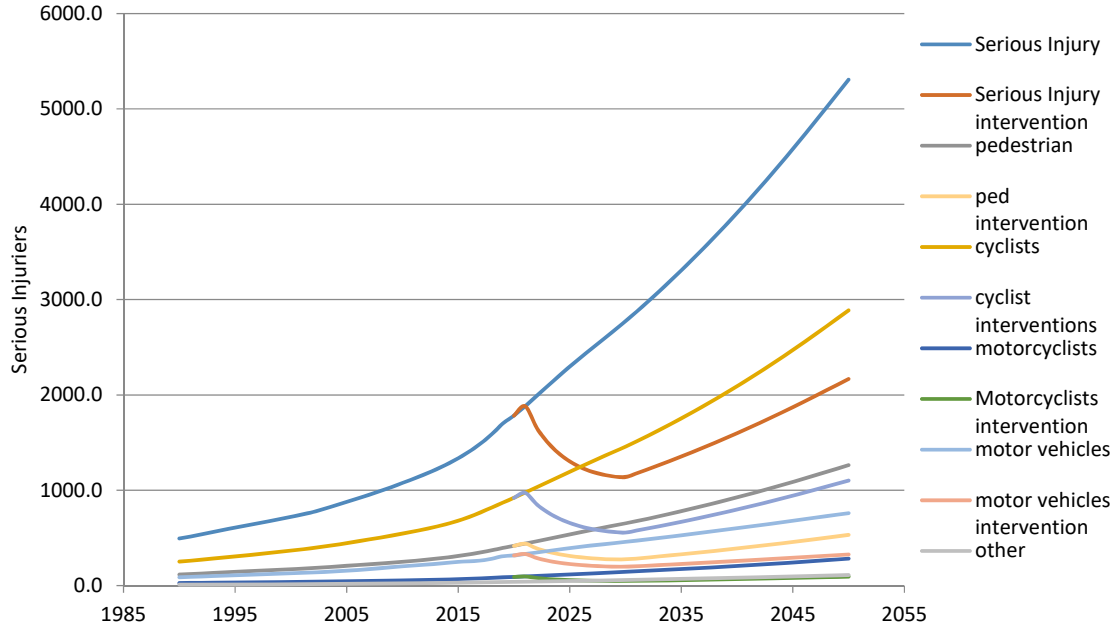


Figure 31: Serious and permanent injury urban female 15 to 19 cohort

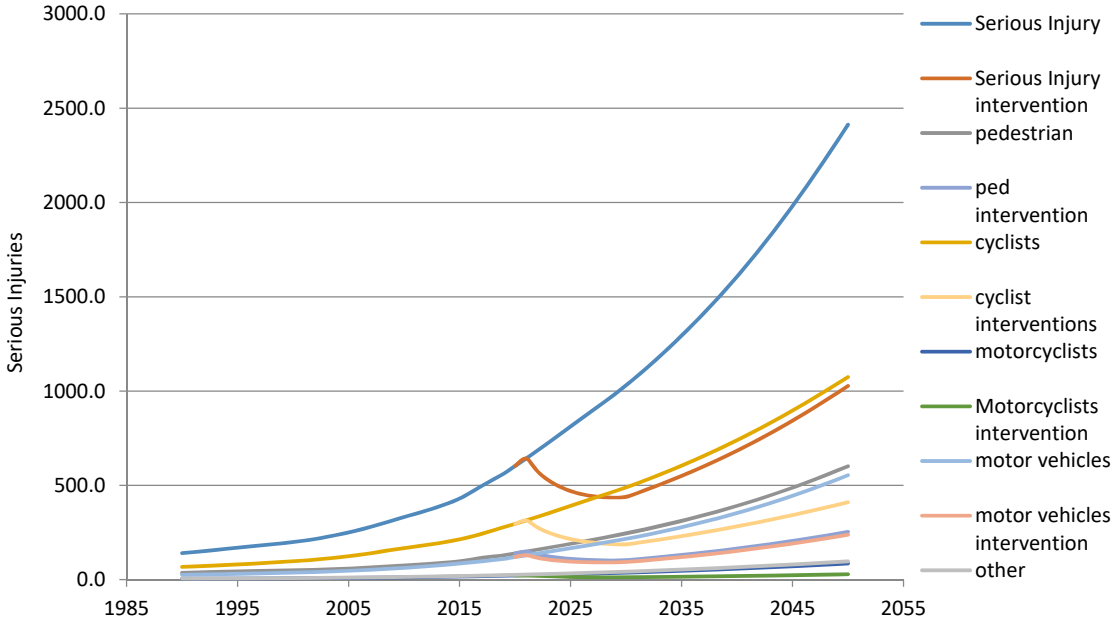


Figure 32: Serious and permanent injury rural male 15 to 19 cohort

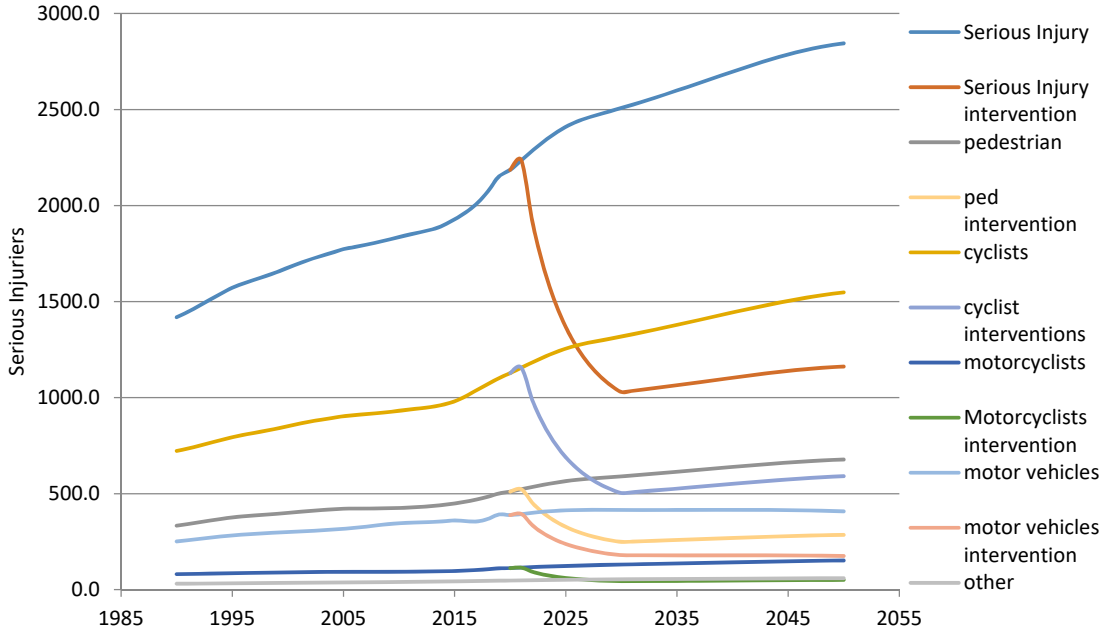
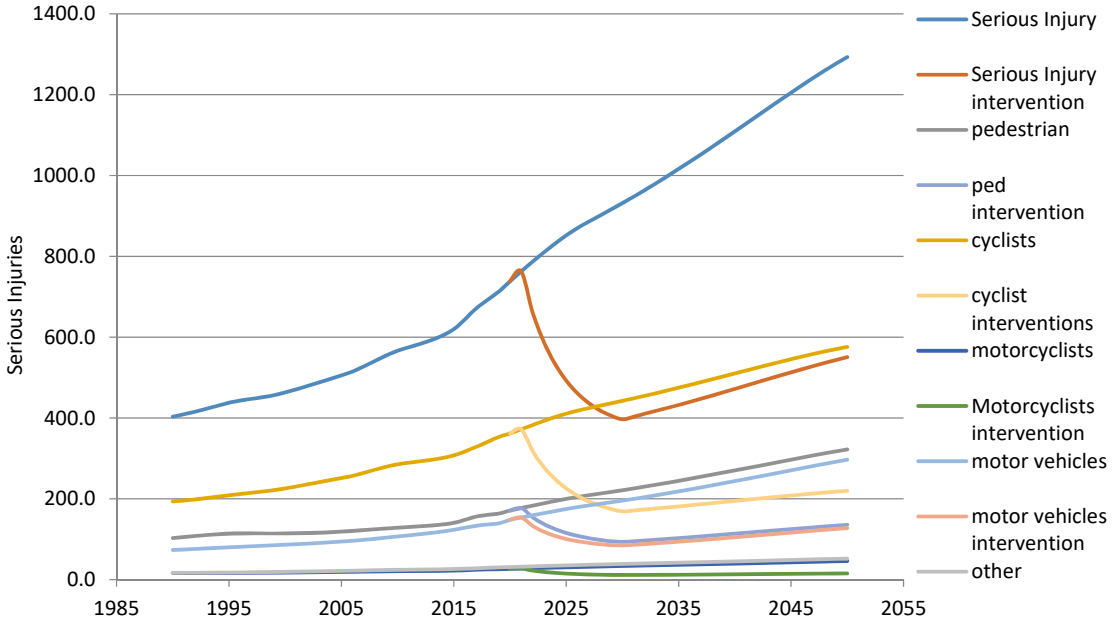


Figure 33: Serious and permanent injury rural female 15 to 19 cohort



20 to 24 cohort

The baseline fatality rates per 100,000 of all modes for males in the 20 to 24 age cohort are expected to gradually decline (Figure 34). However, the same is not true for females, with fatality rates for all modes expected to gradually increase apart from pedestrians (Figure 35). Despite the gradually decreasing fatality rates for males, the rapidly increasing population is expected to lead to an

increase in the baseline from approximately 100 fatalities in 2019 to 270 in 2050. The combination of increasing rates and increasing population is expected to lead to more than a fourfold increase, from 20 fatalities in 2019 to nearly 90 in 2015. The same two modes are responsible for the majority of fatalities for the 20 to 24 age cohort as with the 10 to 14 and 15 to 19 age cohorts: motor vehicle occupants and pedestrians.

Figure 34: Fatalities total male 20 to 24 cohort

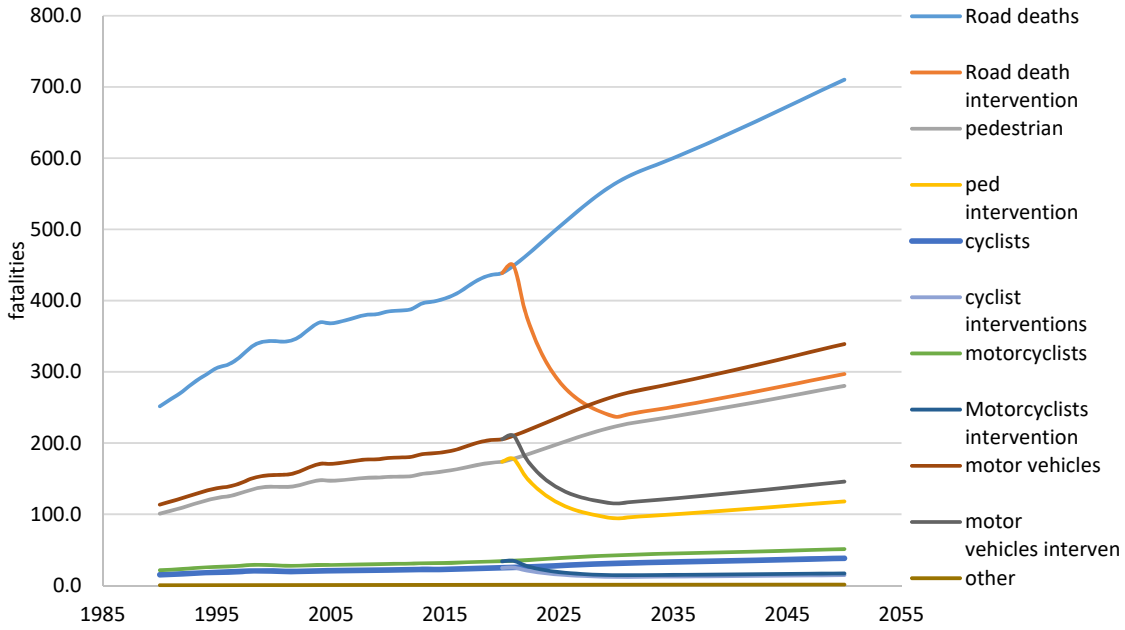
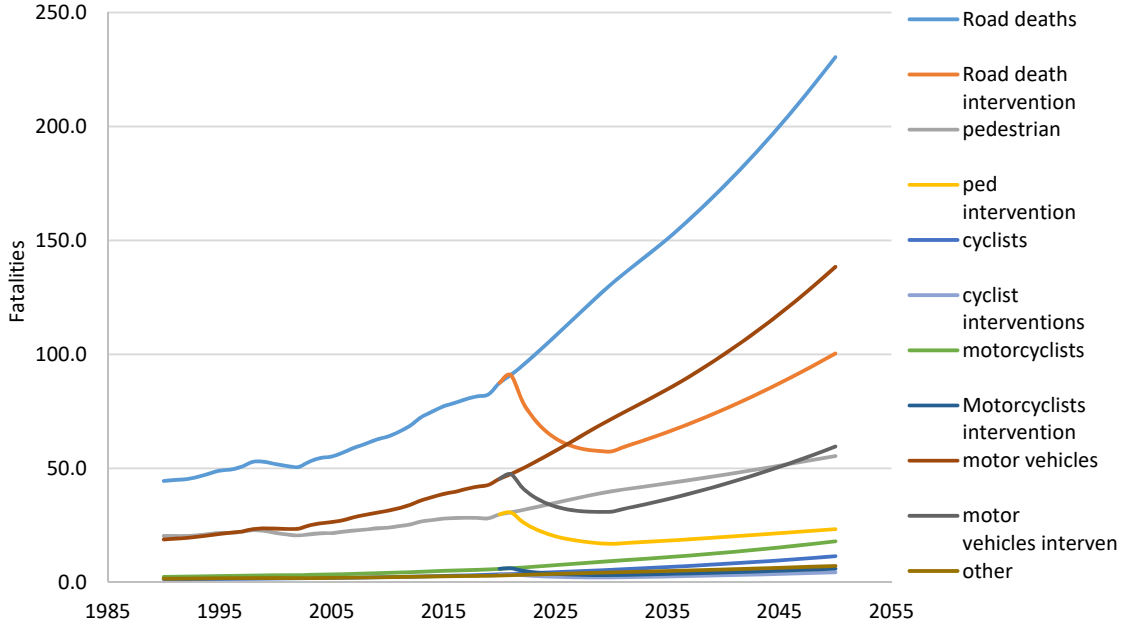


Figure 35: Fatalities total female 20 to 24 cohort



Urban and rural fatalities

The increasingly urban nature of Tanzania is expected to lead to more than doubling of male urban fatalities from approximately 100 per annum in 2019 to over 250 by 2050 (Figure 36). Female fatalities are expected to more than quadruple from 20 to over 80 (Figure 37). For males, these are mostly motor vehicle occupants and pedestrians, with the same for females, with a larger share of motor vehicle occupants into the future. Despite the reduction in the percentage of the population living in rural areas, the number of rural fatalities is still expected to increase by nearly 100 to 2050 for males (Figure 38), while steeply increasing for females (Figure 39).

Figure 36: Fatalities urban male 20 to 24 cohort

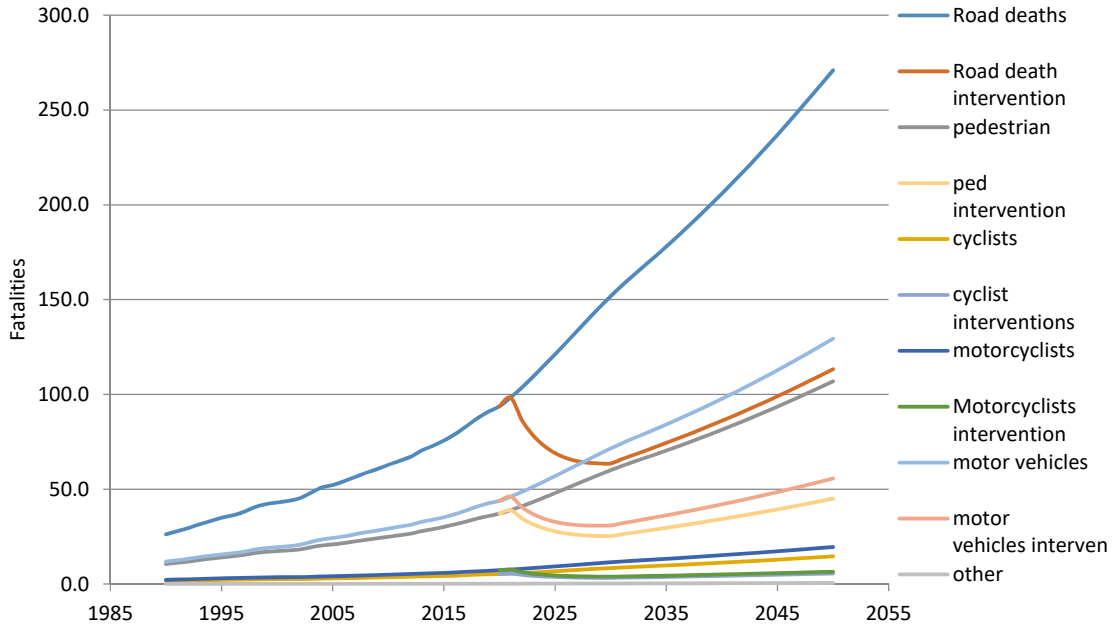


Figure 37: Fatalities urban female 20 to 2 cohort4

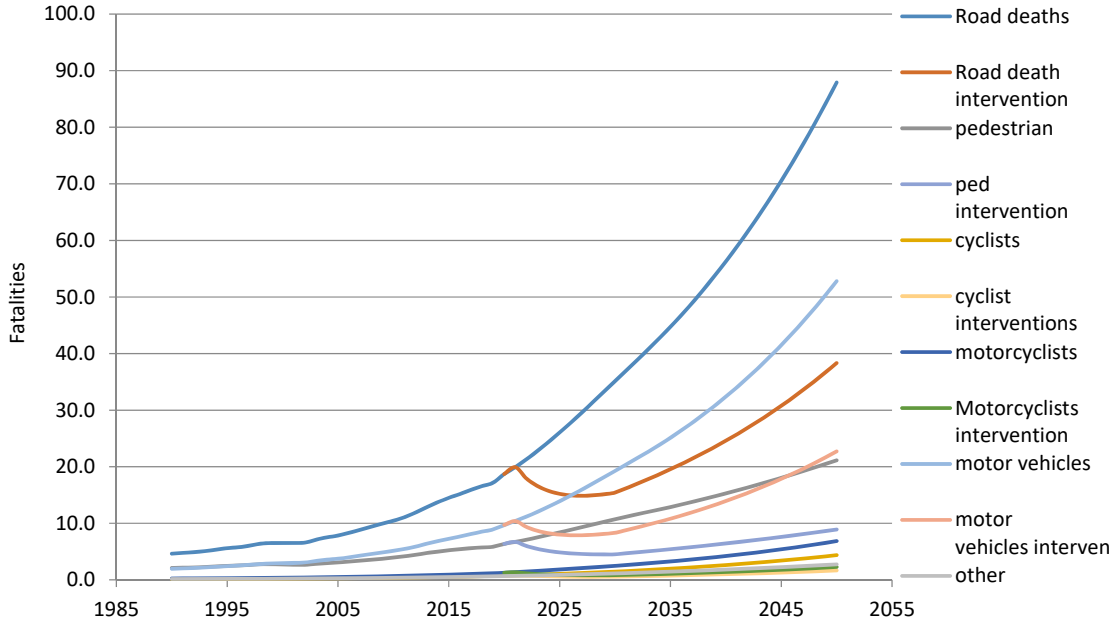


Figure 38: Fatalities rural male 20 to 24 cohort

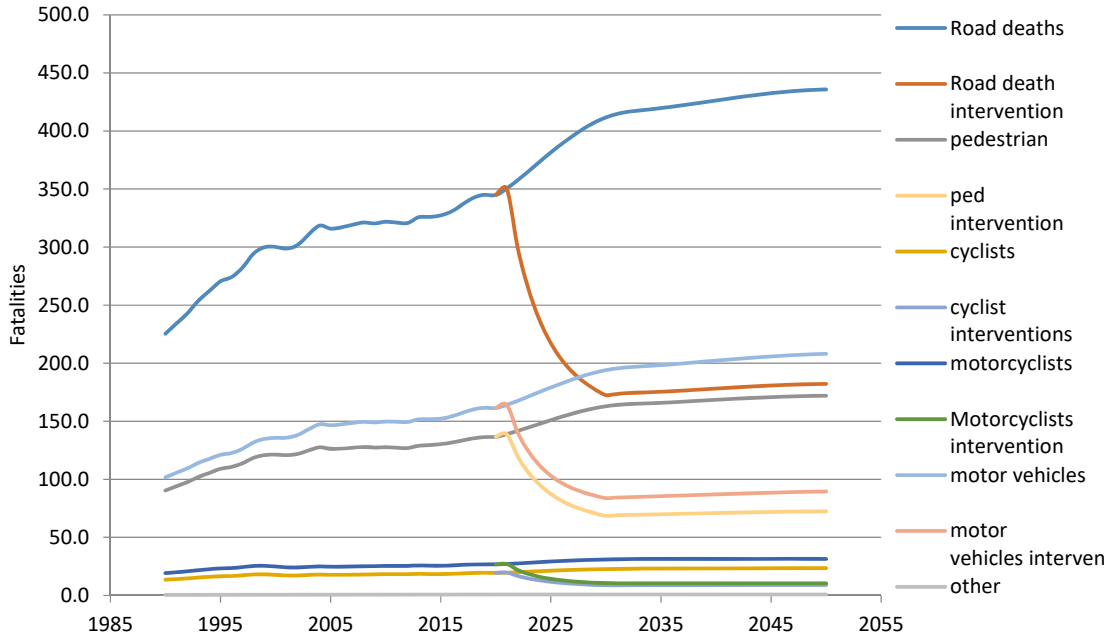
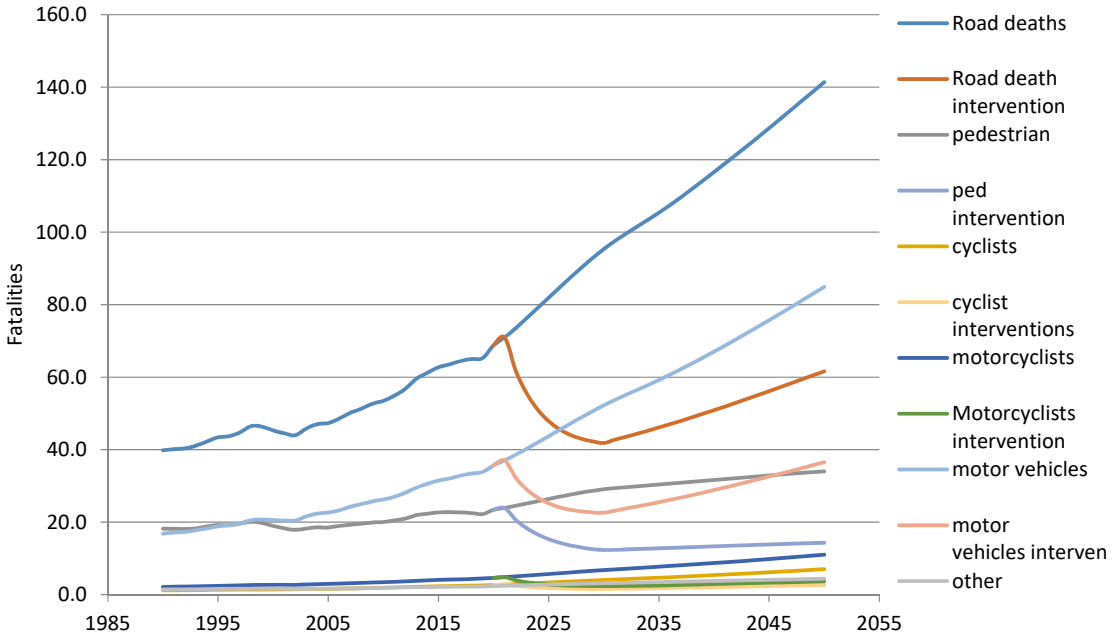


Figure 39: Fatalities rural female 20 to 24 cohort



Serious injuries

The baseline number of serious and permanent injuries is expected to dramatically increase in the coming decades for 20 to 24 year olds. For males, these rise from approximately 4,000 in 2019 to nearly 9,000, and for females they are expected to rise from approximately 1,000 per annum in 2019 to over 3,000 in 2050. However, the distribution of serious injury modes is different in the 20 to 24 cohort as opposed to the younger cohorts, with cyclists representing a smaller proportion (though still the largest) and pedestrian and motor vehicle occupants having larger contributions. This is true for both males and females. This is despite the pedestrian and motor vehicle occupant rates per 100,000 for males declining and the cyclist rate per 100,000 increasing slightly. For females, the baseline rates for all modes per 100,000 is expected to increase, contributing to the tripling of the expected serious injuries, with pedestrians and motor vehicles occupants increasing their share of serious injuries. Consequently, interventions which impact on cyclists and pedestrians would be the most effective in reducing serious injuries, such as infrastructure, speeding and alcohol compliance.

Figure 40: Serious and permanent injury total male 20 to 24 cohort

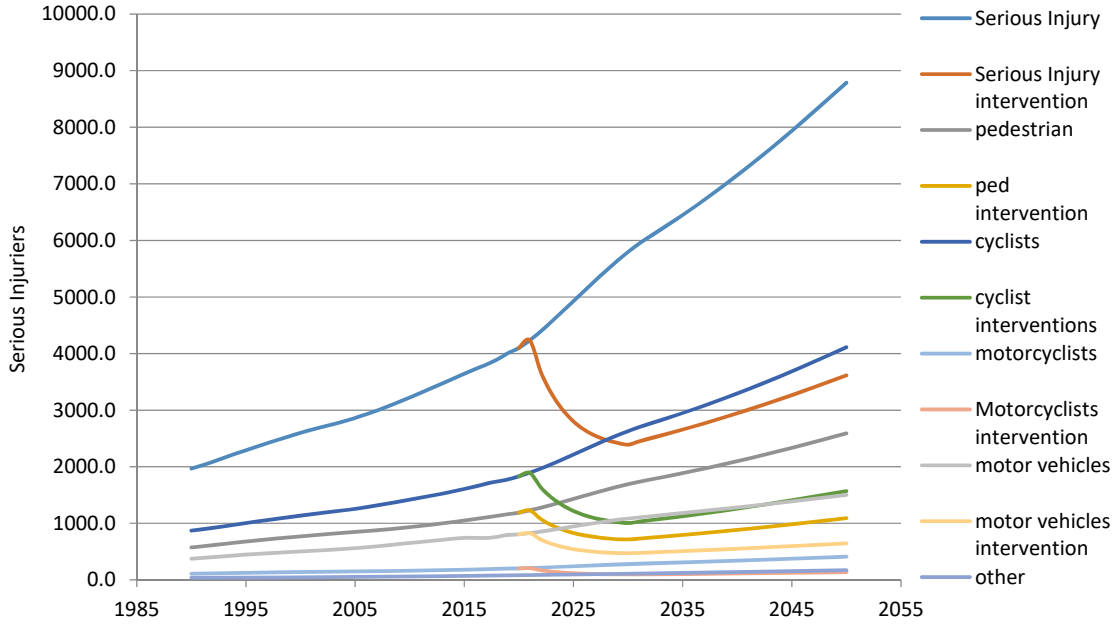
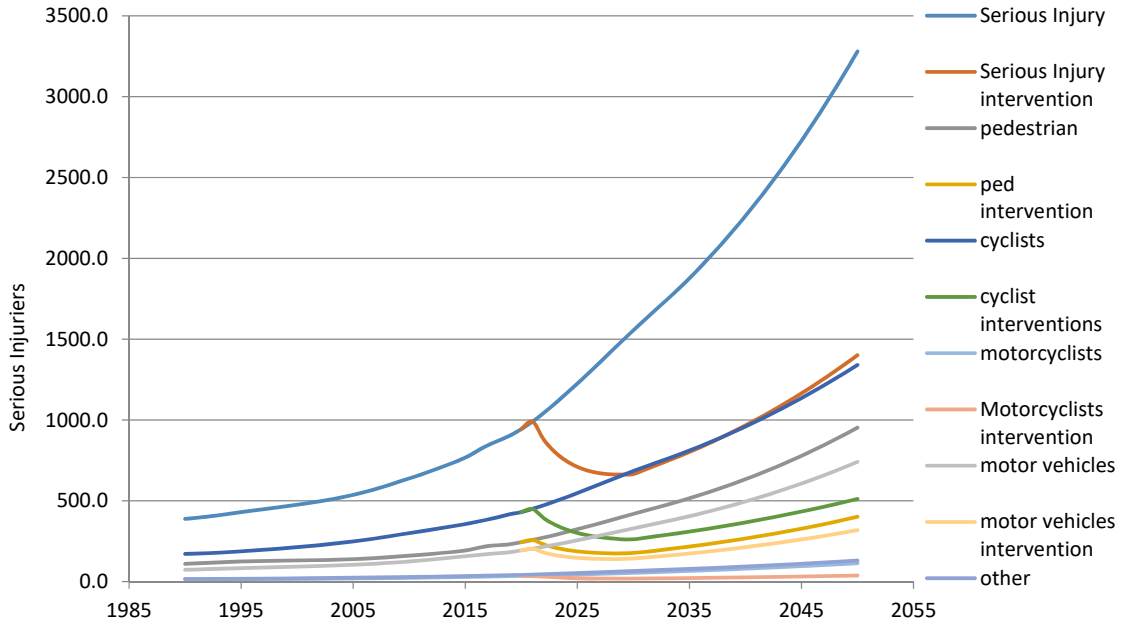


Figure 41: Serious and permanent injury total female 20 to 24 cohort



Urban and rural serious injuries

Both male and female serious injuries are expected to increase at a substantial rate in urban settings with the same distribution of cyclists, pedestrians and motor vehicle occupants being the main source of serious injuries (Figure 42 and Figure 43).

For the male 20 to 24 cohort, rural serious injuries are expected to increase at a slow rate in the coming decades, while for the female cohort it is expected to double. For both males and females, the dominant source of injuries are cyclists, pedestrians and motor vehicles occupants, in that order for both male and female (Figure 44 and Figure 45).

Figure 42: Serious and permanent injury urban male 20 to 24 cohort

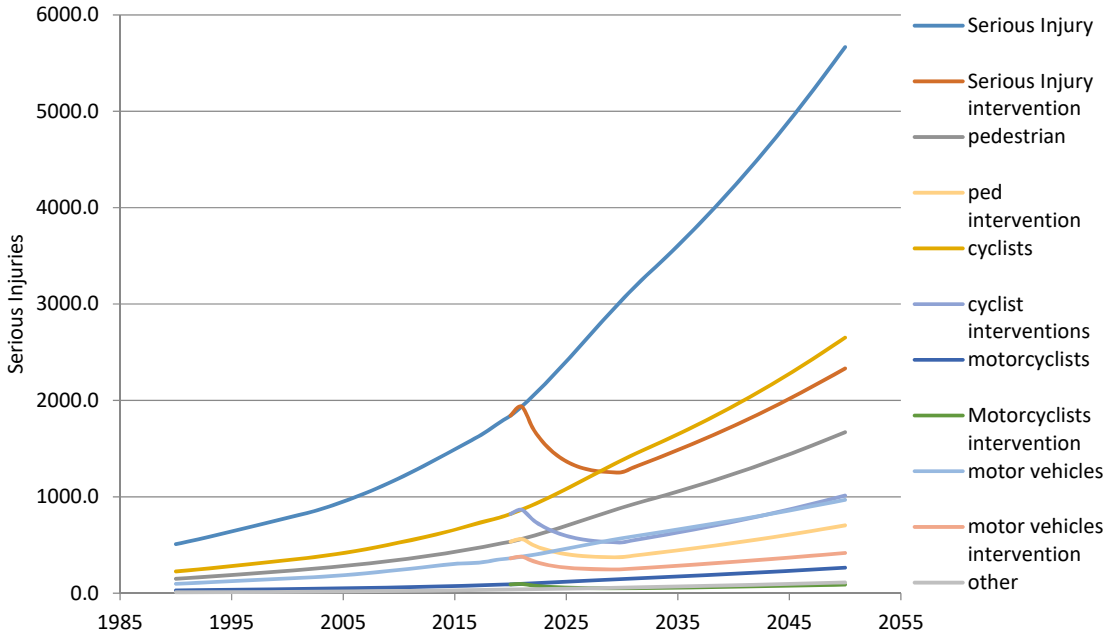


Figure 43: Serious and permanent injury urban female 20 to 24 cohort

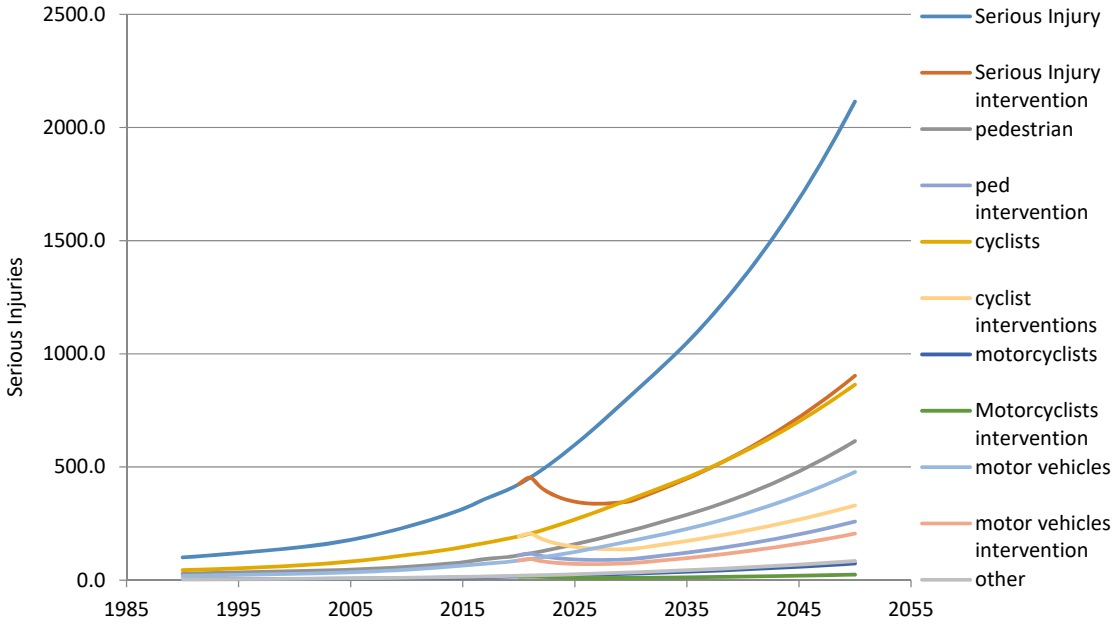


Figure 44: Serious and permanent injury rural male 20 to 24 cohort

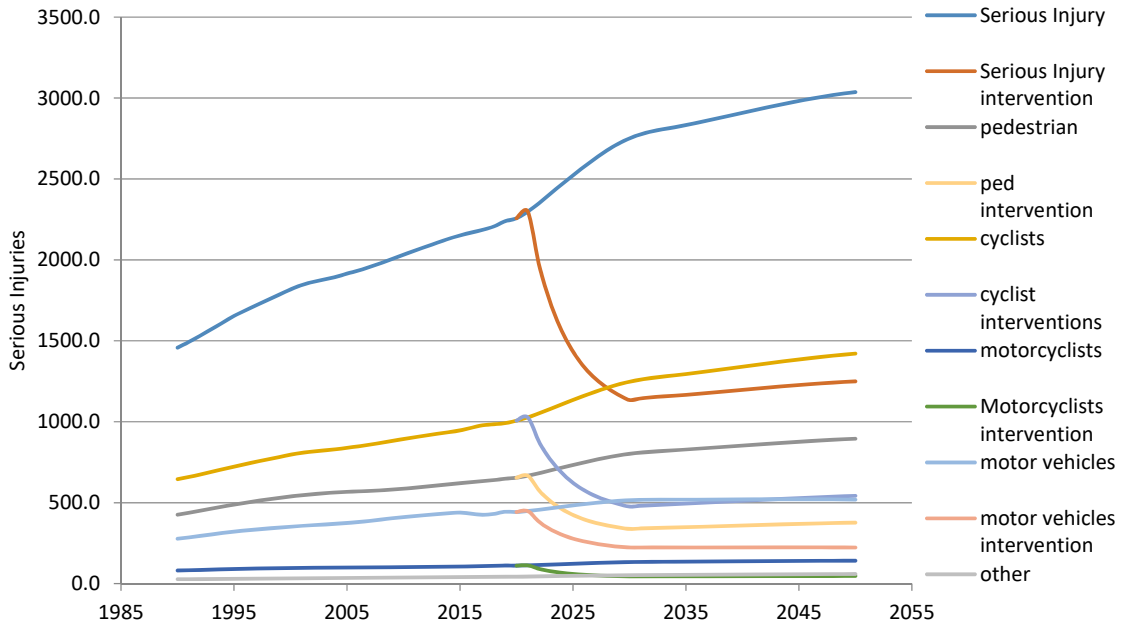
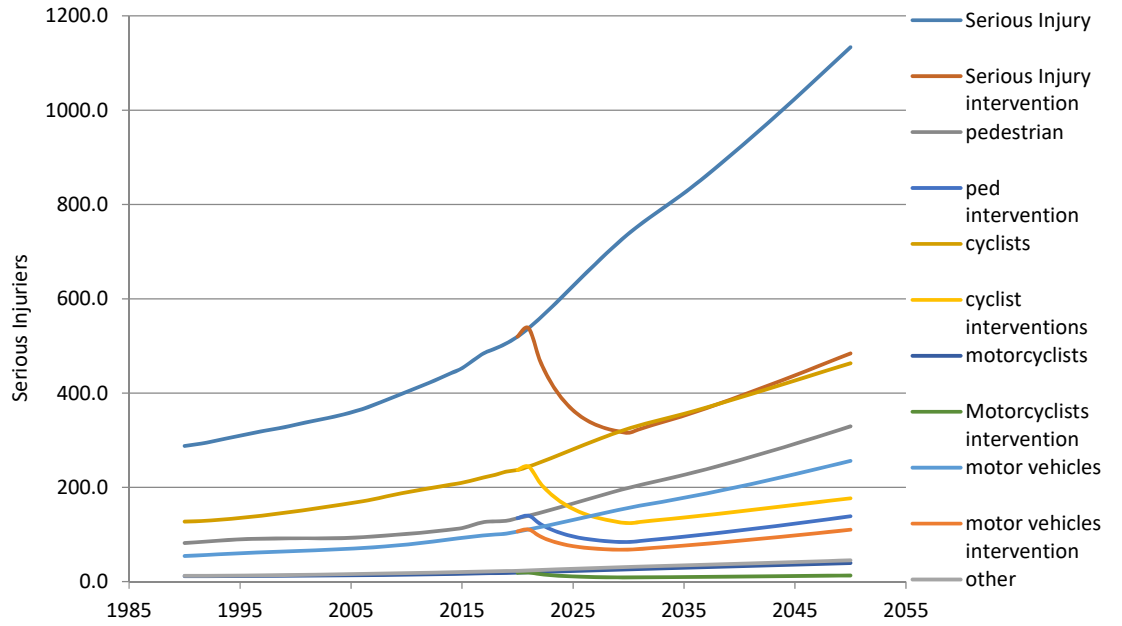


Figure 45: Serious and permanent injury rural female 20 to 24 cohort



Economic Analysis and Optimisation Model

The cost of the all interventions was been calculated out to 2030 with economic benefits estimated from reduced fatalities and averted serious injuries averted. Net present values were calculated using a 3% discount rate. These calculations are used to estimate benefit-cost ratios (BCRs) for

reduced deaths, averted serious injuries, and both deaths and serious injuries for all of Tanzania, as well as disaggregated urban and rural results. For fatalities only, these results show a high BCR for all interventions for the whole country of 2.6. This means that for every $1 dollar invested, it will return an economic benefit of $2.60. When the benefits from serious injuries averted are included, this figure rises to 38.3, i.e., for every $1 dollar invested, it will return an economic benefit of $38.30 (Table 15).

Table 15: Economic benefits all interventions

	Benefits	
Economic benefit, million USD (NPV)	Deaths	$1,591
Economic benefit, million USD (NPV)	Disability	$21,498
Economic benefit, million USD (NPV)	Deaths plus disability	$23,089
Cost, million USD (NPV)		$1,463
Benefit-cost ratio		
Economic benefit	Deaths	2.6
Economic benefit	Deaths plus disability	38.3

When the results are separated into urban and rural areas, this shows a decreased BCR for urban area fatalities (BCR 1.8), but increased BCR when serious injuries are included (47.9) (Table 16). The reverse is true for rural areas, with an increased BCR for fatalities only and decreased BCR for fatalities and serious injuries (3.3 and 30.5) (Table 17).

Table 16: Economic benefits urban areas

	Benefits	
Economic benefit, million USD (NPV)	Deaths	486
Economic benefit, million USD (NPV)	Disability	12,274
Economic benefit, million USD (NPV)	Deaths plus disability	12,760
Cost, million USD (NPV)		$667
Benefit-cost ratio		
Economic benefit	Deaths	1.8
Economic benefit	Deaths plus disability	47.9

Table 17: Economic benefits rural areas

	Benefits	
Economic benefit, million USD (NPV)	Deaths	1,098
Economic benefit, million USD (NPV)	Disability	9,149
Economic benefit, million USD (NPV)	Deaths plus disability	10,247
Cost, million USD (NPV)		$796
Benefit-cost ratio		
Economic benefit	Deaths	3.3
Economic benefit	Deaths plus disability	30.5

Optimisation model

The optimisation model has been constructed in two ways with different objective functions for each. Firstly, to achieve a certain percentage reduction in fatalities or serious injuries at minimum cost, and secondly, for a given financial constraint, to minimise fatalities or serious injuries. For Tanzania, a 50% reduction was specified for both fatalities and serious injuries, and 0.15% of GDP for the second objective function.

Minimise cost for percentage reduction model

With a 50% reduction in fatalities goal achieved with least cost, the optimisation model selected the following interventions to achieve that figure:

- motor vehicle infrastructure;
- pedestrian infrastructure;
- speed enforcement;
- public awareness campaigns; and
- graduated licensing scheme.

The multiplicative nature of the interventions means that each added intervention has a diminishing return, and consequently only two interventions can achieve most of the reduction shown. All the other interventions only achieve an additional 10% reduction in fatalities.

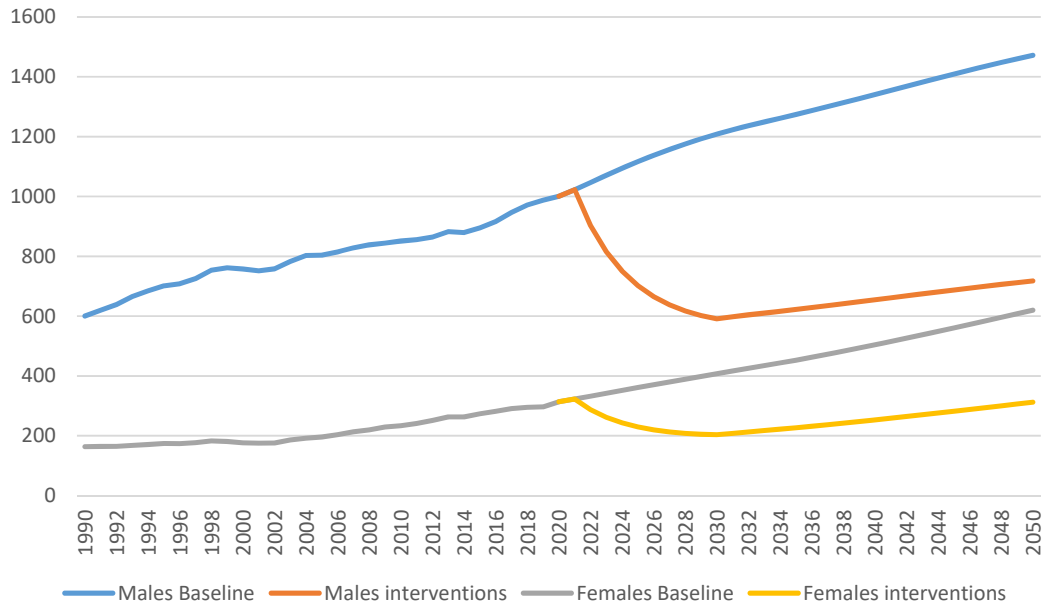
It should be noted that while the goal of this configuration of the model has reduced fatalities as a goal, the interventions also reduce serious injuries, in this case a 33.4% reduction.

This optimisation solution achieves a 50.8% reduction in fatalities in 2030, from 1,616 to 795 with a BCR of 2.7 for fatalities and 26.9 when serious injuries are included (Table 18 and Figure 46).

Table 18: Minimise cost with 50% reduction in fatalities

	Benefits	
Economic benefit, million USD (NPV)	Deaths	1,342
Economic benefit, million USD (NPV)	Disability	12,023
Economic benefit, million USD (NPV)	Deaths plus disability	13,364
Cost, million USD (NPV)		$508
Benefit-cost ratio		
Economic benefit	Deaths	2.7
Economic benefit	Deaths plus disability	26.9

Figure 46: Minimise cost with 50% reduction in fatalities graph



With a 50% reduction in serious injuries goal achieved with least cost, the optimisation model selected the following interventions to achieve that figure:

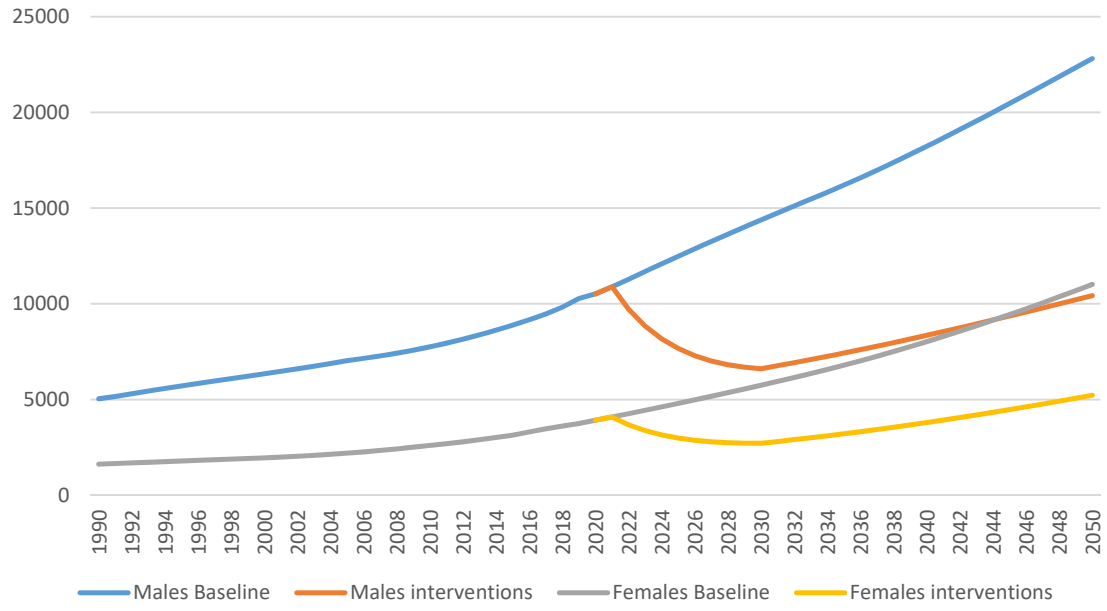
- motorcycle helmet enforcement;
- cyclist infrastructure;
- pedestrian infrastructure;
- speed enforcement;
- public awareness campaigns; and
- seat belt enforcement.

This optimisation solution achieves a 50.1% reduction in serious injuries by 2030, from a projected 20,138 to 10,041 serious injuries with BCRs of 5.2 and 80.7. These interventions also reduced the forecast number of fatalities by 39.2% from a projected 1,616 to 983 (Table 19 and Figure 47).

Table 19: Minimise cost with 50% reduction in serious injuries

	Benefits	
Economic benefit, million USD (NPV)	Deaths	1,336
Economic benefit, million USD (NPV)	Disability	19,341
Economic benefit, million USD (NPV)	Deaths plus disability	20,677
Cost, million USD (NPV)		$794
Benefit-cost ratio		
Economic benefit	Deaths	5.2
Economic benefit	Deaths plus disability	80.7

Figure 47: Minimise cost with 50% reduction in serious injuries graph



Minimum fatalities/injuries for percentage GDP model

With a constraint of 0.15% of GDP to minimise fatalities goal, the optimisation model selected the following interventions:

- motorcycle helmet enforcement;

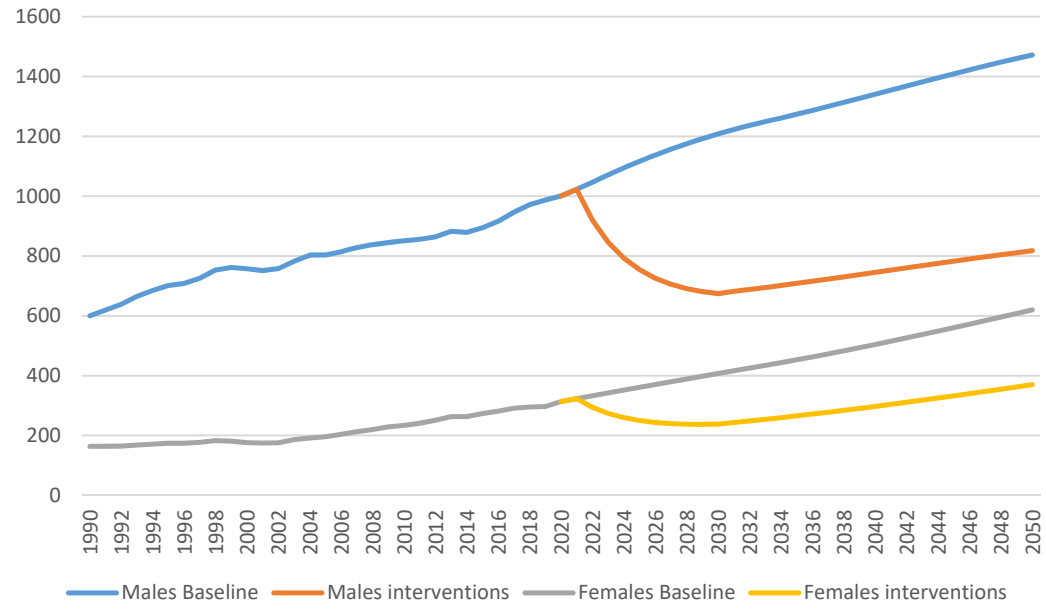
- alcohol enforcement;
- pedestrian infrastructure;
- speed enforcement;
- public awareness campaigns;
- graduated licensing scheme;
- seat belt enforcement; and
- car safety standards.

This optimisation solution achieves a 43.5% reduction in fatalities in 2030 from 1,616 to 909, with a BCR of 4.0 for fatalities and 45.4 when serious injuries are included. This solution also reduced serious injuries from 20,134 to 13,488, a 33.0% reduction (Table 20 and Figure 48).

Table 20: Minimise fatalities with 0.15% GDP constraint

	Benefits	
Economic benefit, million USD (NPV)	Deaths	1,152
Economic benefit, million USD (NPV)	Disability	11,909
Economic benefit, million USD (NPV)	Deaths plus disability	13,061
Cost, million USD (NPV)		$763
Benefit-cost ratio		
Economic benefit	Deaths	4.0
Economic benefit	Deaths plus disability	45.4

Figure 48: Fatalities with 0.15% GDP constraint



With a constraint of 0.15% of GDP to minimise serious injuries goal, the optimisation model selected the following interventions:

- motorcycle helmets;
- alcohol limit enforcement;
- pedestrian infrastructure;
- cyclist infrastructure;
- speed enforcement;

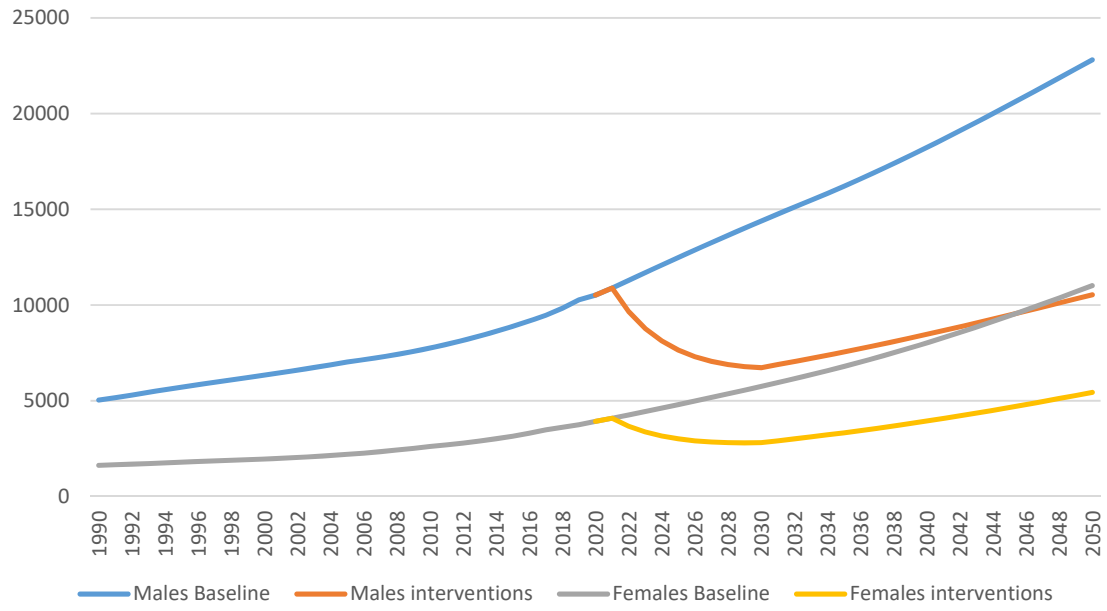
- public awareness campaigns;
- graduated licensing scheme; and
- car safety standards.

This optimisation solution achieves a 52.6% reduction in serious injuries by 2030, from 20,134 to 9,528, with a BCR of 4.0 for fatalities and 70.8 when serious injuries are included. This solution also reduced serious injuries from 1,616 to 917, a 43.2% reduction (Table 21 and Figure 49).

Table 21: Minimise serious injuries with a 0.15% GDP constraint

Benefits		
Economic benefit, million USD (NPV)	Deaths	1,137
Economic benefit, million USD (NPV)	Disability	19,047
Economic benefit, million USD (NPV)	Deaths plus disability	20,185
Cost, million USD (NPV)		$779
Benefit-cost ratio		
Economic benefit	Deaths	4.0
Economic benefit	Deaths plus disability	70.8

Figure 49: Serious injuries with a 0.15% GDP constraint



Summary and Conclusion

This case study has drawn upon available evidence from both published research, survey work and intervention programs undertaken in Tanzania as part of Amend's programs to make the journey to school a safer one. Amend's programs have shown the effectiveness of infrastructure in reducing speeds around schools with a commensurate reduction in road traffic accidents. The speed survey results from infrastructure interventions are consistent with those used by the International Road Assessment Program (iRAP) in their road safety star rating modelling, and as a result an approach consistent with iRAP's 3 Star or Better by 2030 campaign was used in this case study in terms of

infrastructure improvements and associated economic costs. Despite this, data specific to Tanzania is relatively limited and few additional data points specific to Tanzania have been incorporated into the model apart from levels of serious and permanent injuries being 5.6% (up from 4.1%).

The results for each age cohort are similar, with motor vehicle occupants and pedestrians making up the vast majority of fatalities for both males and females. However, the difference between urban and rural fatalities is forecast to be significant. Urban fatalities are projected to increase dramatically for both males and females, whereas rural fatalities show male fatalities plateauing and females slightly increasing across all age cohorts. This is primarily driven by the increasing urbanisation of Tanzania, as the fatality rates are all slightly decreasing for 10 to 14 year olds for all modes for both genders. The same is not true for 15 to 19 and 20 to 24 year olds, as male modes show a decreasing fatality trend, while most modes show an increase for females.

The results for serious injuries differ significantly from fatalities, with there being more than 10 times as many serious injuries as fatalities and increasing at a greater rate than fatalities, so by 2050 serious injuries are expected to be more than 16 times the number of fatalities. Well over half of all serious injuries occur to cyclists, with pedestrian and motor vehicle occupants represent much smaller levels. The proportion of cyclists decreases through increasing age cohorts (male 10 to 14 ~60%, female 55%, male and female 15 to 19 ~50%, male and female 20 to 24 ~45%), with motor vehicles and pedestrians increasing as cyclists decrease. Nearly all modes for males for 10 to 14 and 15 to 19 year olds show an increasing serious injury rate trend, with declining trends for 20 to 24 year olds from a very high level. This is unexpected as in most settings, the 20 to 24 year old age cohort has the highest rates of fatalities and serious injuries with increasing trends. This differs from females who show an increasing serious injury trend for all modes across all age cohorts.

The effect of implementing all interventions leads to a 58% reduction in fatalities by 2030 when they are fully implemented and 59% reduction in serious injuries.

Due to the multiplicative nature of the interventions, each additional intervention has a diminishing impact on the reduction in fatalities or serious injuries. To illustrate this point, when the optimisation model was set to achieve a 50% reduction in fatalities, this was achieved by only 2 interventions: infrastructure and speed compliance.

When all interventions are modelled, the economic analysis of these results show benefit-cost ratios of 2.6 for fatalities and 38.3 when serious injuries are included. When disaggregated into urban and rural areas, these results show BCRs of 1.8 for fatalities and 47.9 when serious injuries are included for urban areas and 3.3 and 30.5 for rural areas.

When a 50% reduction in fatalities was modelled at least cost in the optimisation model, the BCR was 2.7 for fatalities and 26.9 when serious injuries were included. When the 50% reduction goal was for serious injuries, the BCRs were 5.2 for fatalities and 80.7 when serious injuries were included. The second optimisation model with a 0.15% GDP limit to minimise fatalities achieved a BCR of 4.0 for fatalities and 45.4 with serious injuries. However, when the goal was to minimise serious injuries, the BCRs were 4.0 and 70.8.

Overall, the economic analysis demonstrates the interventions achieve a large return, and also highlights the importance of serious injuries, with the BCRs usually being an order of magnitude higher than fatalities alone.

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Appendix 1: Number of Fatalities

Annual baseline and interventions for fatalities are shown in Table 22 and Table 23.

Table 22: Baseline and intervention fatalities

Year	Males and females	
	Baseline	Interventions
1990	764	
1991	784	
1992	803	
1993	833	
1994	856	
1995	876	
1996	882	
1997	902	
1998	936	
1999	943	
2000	934	
2001	926	
2002	934	
2003	969	
2004	995	
2005	1000	
2006	1018	
2007	1041	
2008	1058	
2009	1073	
2010	1085	
2011	1097	
2012	1115	
2013	1146	
2014	1142	
2015	1168	
2016	1198	
2017	1238	
2018	1267	
2019	1284	
2020	1314	1314
2021	1346	1346
2022	1379	1137
2023	1413	988
2024	1446	880
2025	1478	800
2026	1508	741
2027	1537	696
2028	1565	663
2029	1591	673
2030	1616	683
2031	1639	693
2032	1661	702
2033	1683	710
2034	1705	719
2035	1727	729
2036	1749	738
2037	1773	748
2038	1796	758
2039	1821	768
2040	1845	778
2041	1870	789

2042	1894	799
2043	1919	810
2044	1944	821
2045	1969	831
2046	1994	842
2047	2019	853
2048	2044	863
2049	2068	873
2050	2092	883

Table 23: Baseline and intervention fatalities male and female

Year	Males		Females	
	Baseline	Interventions	Baseline	Interventions
1990	600		164	
1991	620		164	
1992	639		165	
1993	665		168	
1994	685		171	
1995	701		174	
1996	708		174	
1997	725		177	
1998	753		183	
1999	762		181	
2000	757		176	
2001	751		175	
2002	758		176	
2003	783		186	
2004	803		192	
2005	804		196	
2006	814		204	
2007	828		213	
2008	838		220	
2009	844		229	
2010	851		234	
2011	856		241	
2012	864		251	
2013	883		263	
2014	879		263	
2015	895		273	
2016	916		281	
2017	947		291	
2018	972		295	
2019	987		297	
2020	1001	1001	314	314
2021	1023	1023	323	323
2022	1046	862	332	275
2023	1071	747	342	241
2024	1094	663	352	217
2025	1117	601	361	199
2026	1138	555	371	186
2027	1157	520	380	176
2028	1176	494	389	169
2029	1193	500	398	173
2030	1209	506	407	177
2031	1223	512	416	180
2032	1236	517	425	184
2033	1249	522	434	188
2034	1261	527	443	192
2035	1274	533	453	196

2036	1287	538	463	200
2037	1300	543	473	204
2038	1314	549	483	209
2039	1327	555	493	213
2040	1341	561	504	218
2041	1355	566	515	223
2042	1368	572	526	227
2043	1382	578	537	232
2044	1396	584	549	237
2045	1409	589	560	242
2046	1422	595	572	247
2047	1435	600	584	252
2048	1448	606	596	257
2049	1460	611	608	263
2050	1472	616	620	268

Appendix 2: Number of Serious Injuries

Annual baseline and interventions for fatalities are shown in Table 24 and Table 25.

Table 24: Baseline and intervention serious injuries

Year	Males and females	
	Baseline	Interventions
1990	6666	
1991	6817	
1992	6984	
1993	7162	
1994	7342	
1995	7523	
1996	7676	
1997	7821	
1998	7967	
1999	8123	
2000	8295	
2001	8471	
2002	8646	
2003	8826	
2004	9019	
2005	9228	
2006	9417	
2007	9623	
2008	9846	
2009	10088	
2010	10357	
2011	10638	
2012	10946	
2013	11280	
2014	11642	
2015	12031	
2016	12473	
2017	12945	
2018	13448	
2019	14026	
2020	14440	14440
2021	14977	14977
2022	15540	12821
2023	16121	11264
2024	16706	10124
2025	17286	9281
2026	17860	8659
2027	18433	8205
2028	19002	7879
2029	19569	8108
2030	20134	8338
2031	20695	8567
2032	21256	8796
2033	21821	9028
2034	22398	9265
2035	22993	9511
2036	23607	9763
2037	24241	10024
2038	24894	10294
2039	25564	10571
2040	26247	10853
2041	26949	11144

2042	27667	11440
2043	28398	11743
2044	29143	12051
2045	29898	12363
2046	30667	12681
2047	31445	13003
2048	32233	13329
2049	33026	13657
2050	33824	13987

Table 25: Baseline and intervention serious injuries male and female

Year	Males		Females	
	Baseline	Interventions	Baseline	Interventions
1990	5039		1627	
1991	5161		1656	
1992	5296		1689	
1993	5438		1724	
1994	5582		1760	
1995	5726		1797	
1996	5848		1828	
1997	5966		1855	
1998	6085		1882	
1999	6210		1913	
2000	6344		1951	
2001	6476		1994	
2002	6606		2040	
2003	6737		2089	
2004	6876		2143	
2005	7027		2201	
2006	7154		2262	
2007	7284		2339	
2008	7421		2425	
2009	7573		2515	
2010	7751		2606	
2011	7944		2694	
2012	8154		2792	
2013	8381		2899	
2014	8626		3016	
2015	8890		3141	
2016	9165		3308	
2017	9467		3478	
2018	9832		3616	
2019	10274		3752	
2020	10519	10519	3921	3921
2021	10889	10889	4087	4087
2022	11280	9294	4260	3527
2023	11684	8142	4437	3122
2024	12088	7296	4617	2828
2025	12487	6668	4799	2613
2026	12877	6201	4984	2458
2027	13262	5857	5170	2348
2028	13642	5605	5359	2274
2029	14017	5754	5552	2354
2030	14386	5902	5747	2436
2031	14749	6047	5946	2519
2032	15107	6191	6149	2605
2033	15464	6335	6357	2693
2034	15827	6482	6571	2783
2035	16201	6634	6792	2877

2036	16585	6790	7022	2974
2037	16981	6949	7260	3074
2038	17388	7115	7506	3179
2039	17804	7284	7760	3287
2040	18227	7456	8020	3397
2041	18659	7632	8290	3512
2042	19100	7811	8566	3629
2043	19548	7993	8850	3750
2044	20002	8178	9141	3873
2045	20461	8364	9437	3999
2046	20925	8553	9741	4128
2047	21394	8743	10051	4260
2048	21866	8935	10367	4394
2049	22338	9126	10688	4531
2050	22810	9318	11014	4669

Appendix 3: Transport Mode Trends for Fatalities and Serious Injuries

Trends in fatalities and serious injuries for all modes, both genders and age groups are found from Figure 50 to Figure 109.

Figure 50: 10 to 14 male cohort pedestrian fatality rate per 100,000

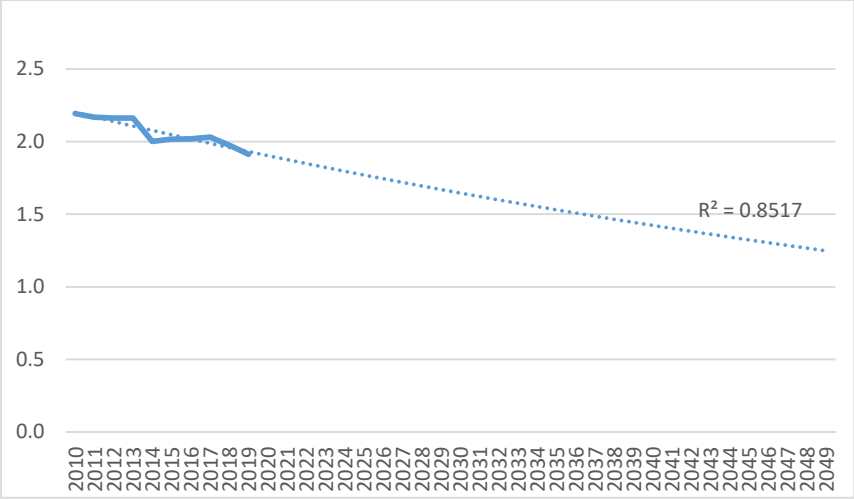

Figure 51: 10 to 14 male cohort cyclists fatality rate per 100,000

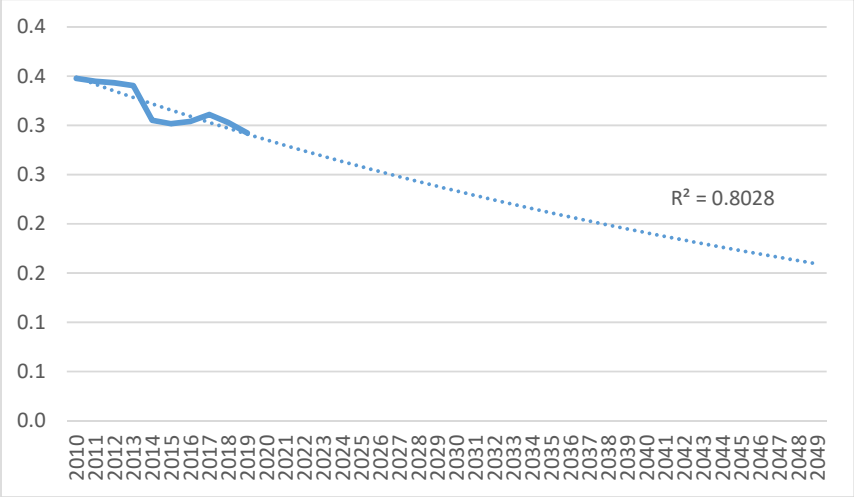

Figure 52: 10 to 14 male cohort motor cyclists fatality rate per 100,000

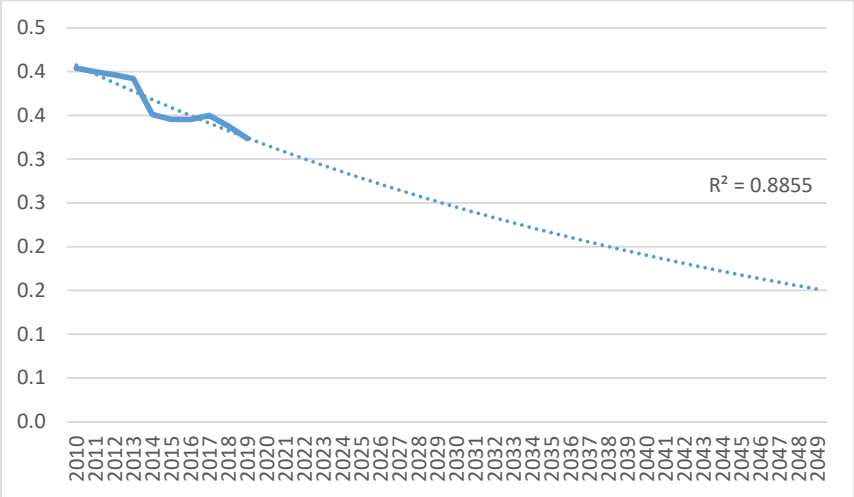

Figure 53: 10 to 14 Male motor vehicles fatality rate per 100,000

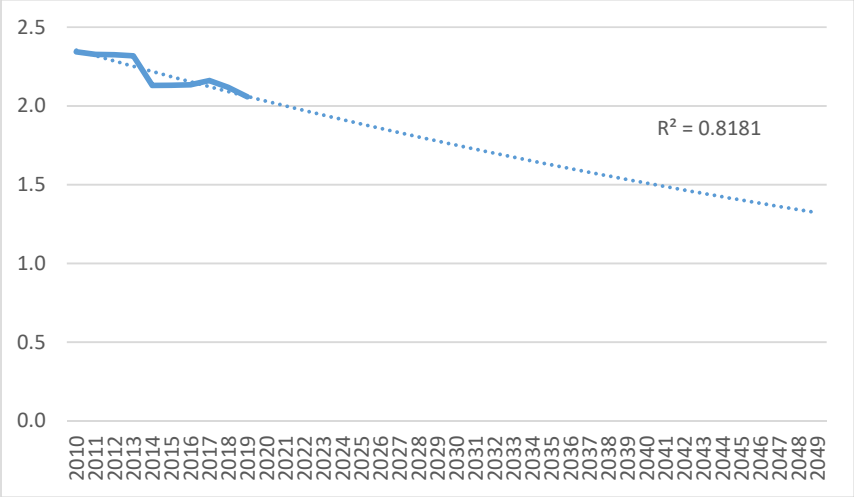

Figure 54: 10 to 14 male cohort other fatality rate per 100,000

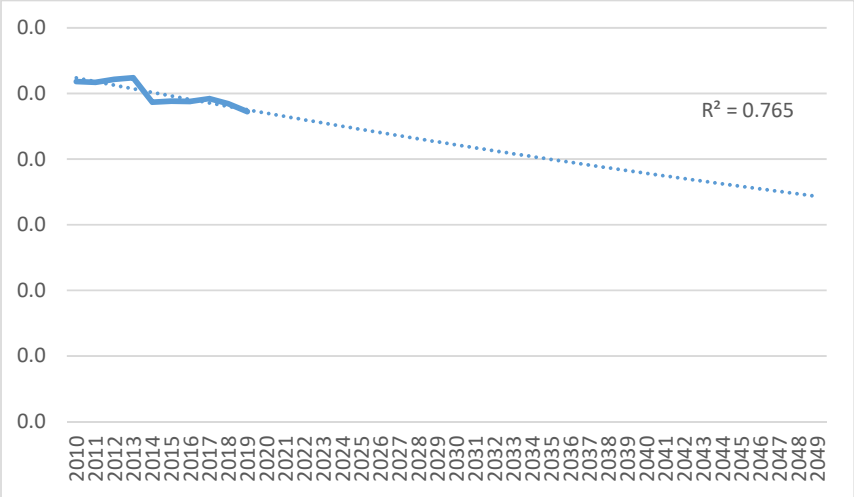

Figure 55: 10 to 14 female cohort pedestrian fatality rate per 100,000

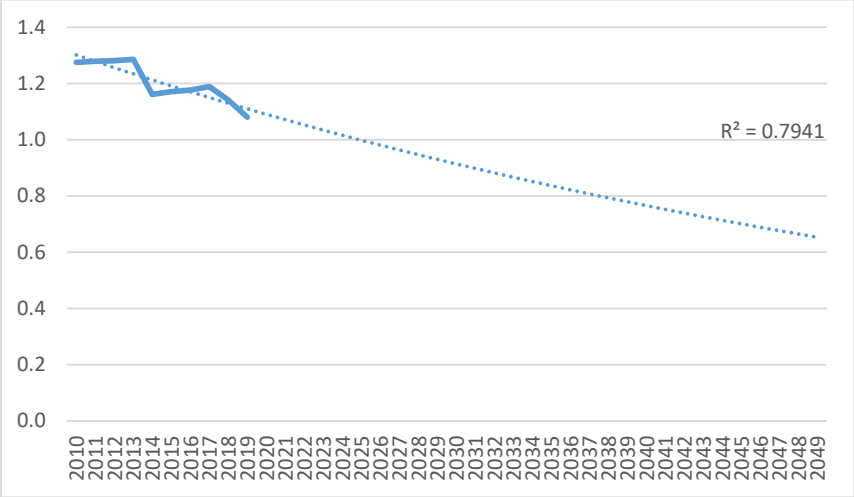

Figure 56: 10 to 14 female cohort cyclists fatality rate per 100,000

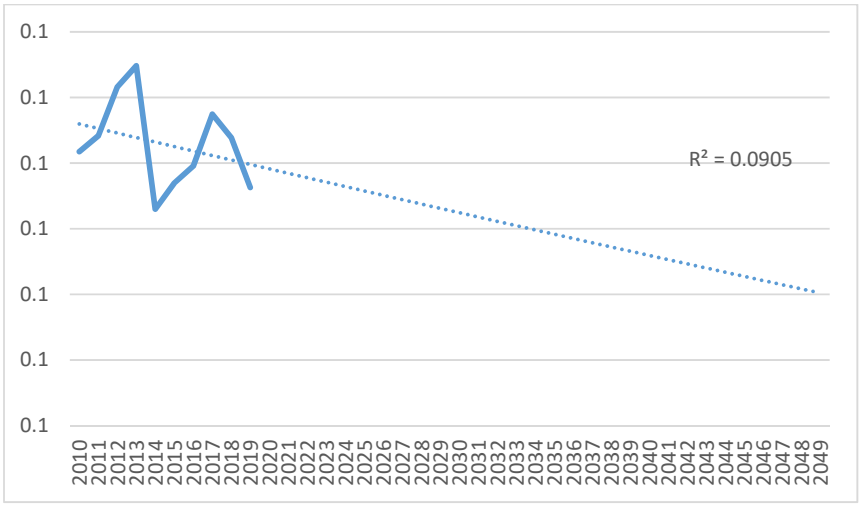

Figure 57: 10 to 14 female cohort motor cyclists fatality rate per 100,000

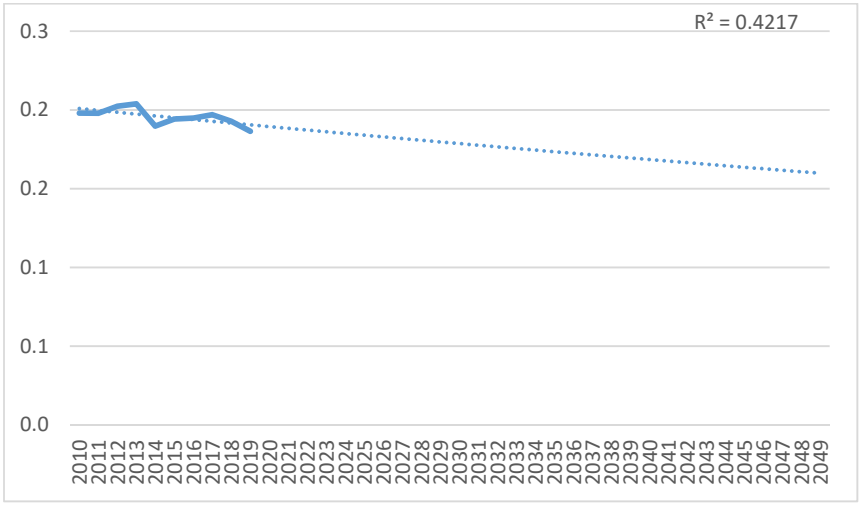

Figure 58: 10 to 14 female cohort motor vehicles fatality rate per 100,000

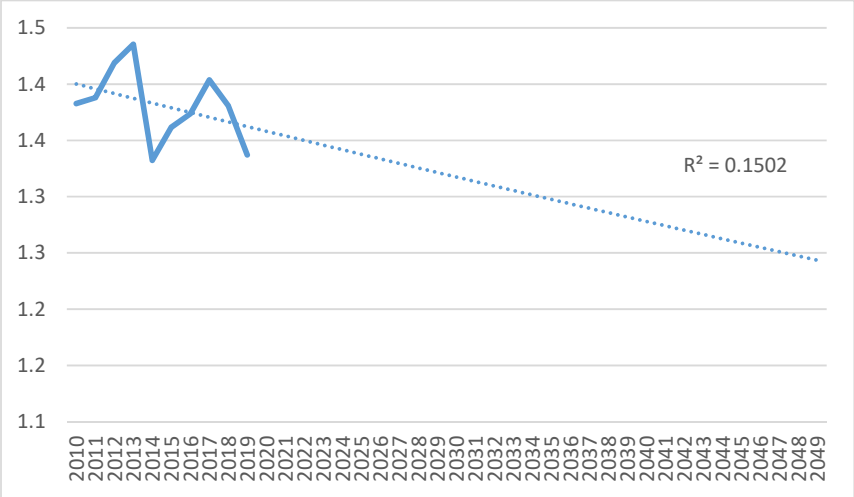

Figure 59: 10 to 14 female cohort other fatality rate per 100,000

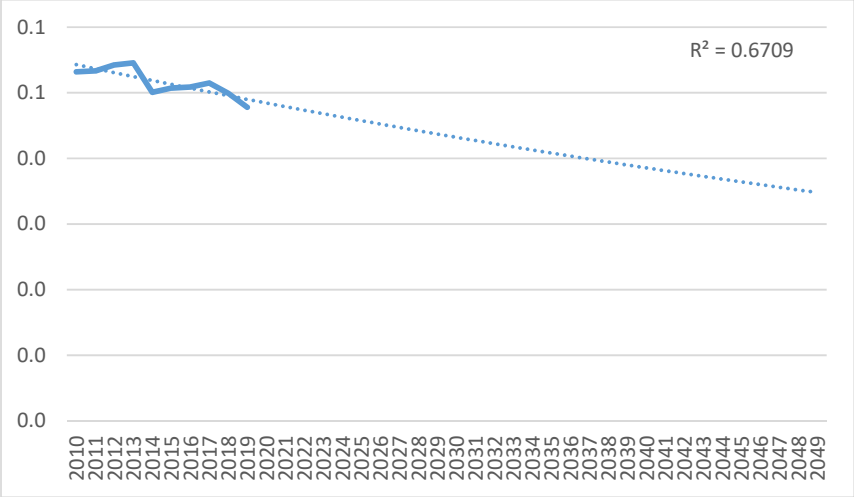

Figure 60: Serious and permanent injury pedestrians male 10 to 14 cohort per 100,000

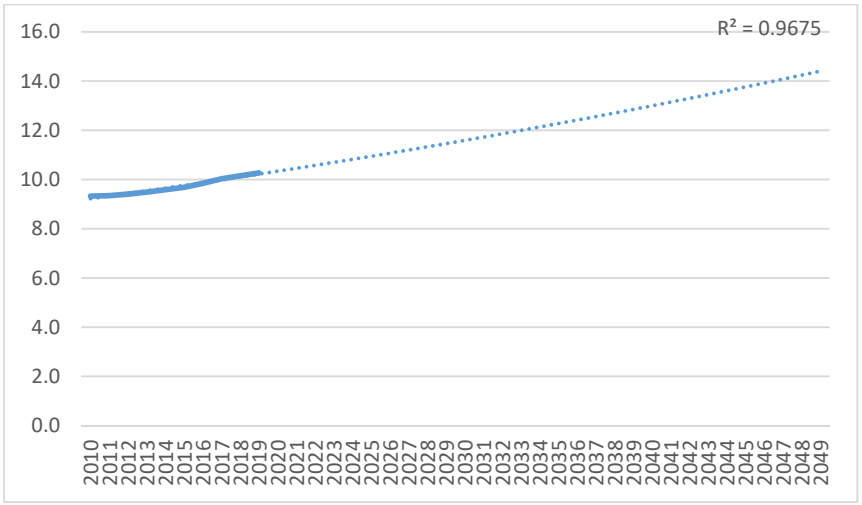

Figure 61: Serious and permanent disability cyclists male 10 to 14 cohort per 100,000

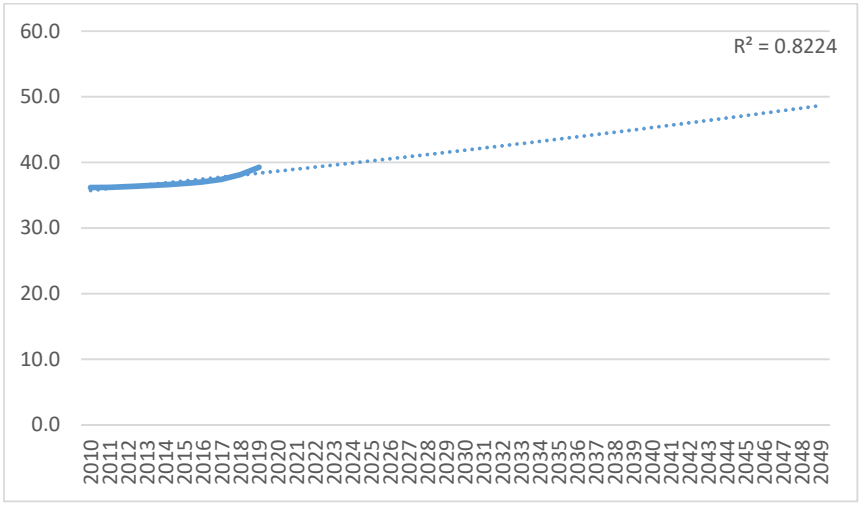

Figure 62: Serious and permanent disability motor cyclists male 10 to 14 cohort per 100,000

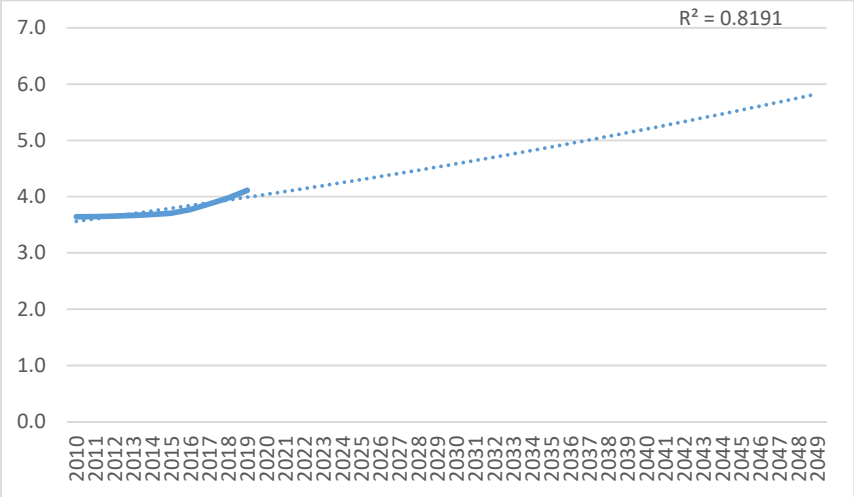

Figure 63: Serious and permanent disability motor vehicles male 10 to 14 cohort per 100,000

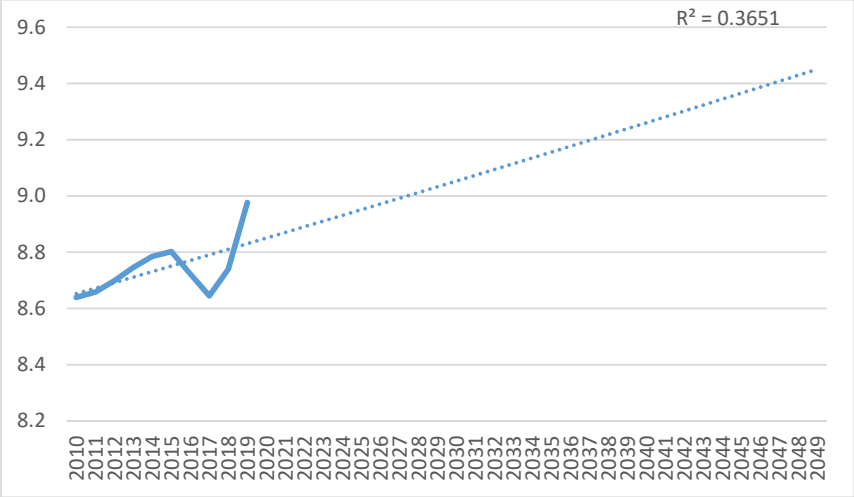

Figure 64: Serious and permanent disability other male 10 to 14 cohort per 100,000

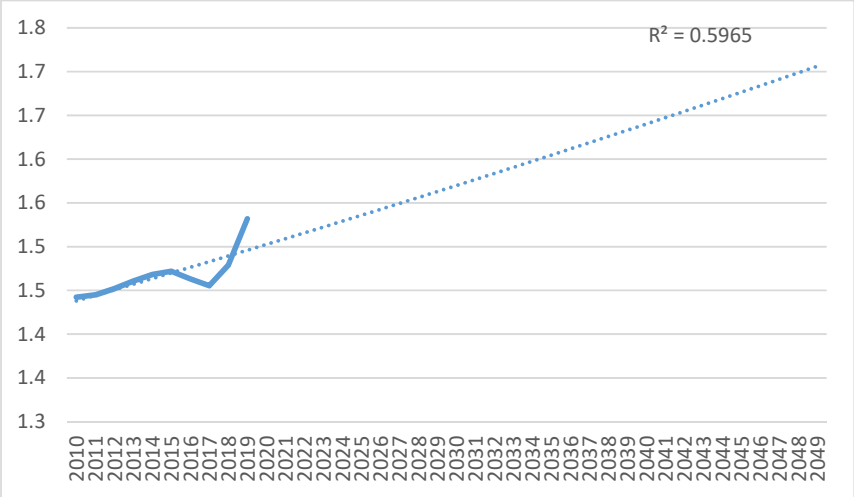

Figure 65: 10 to 14 female cohort pedestrian serious injury rate per 100,000

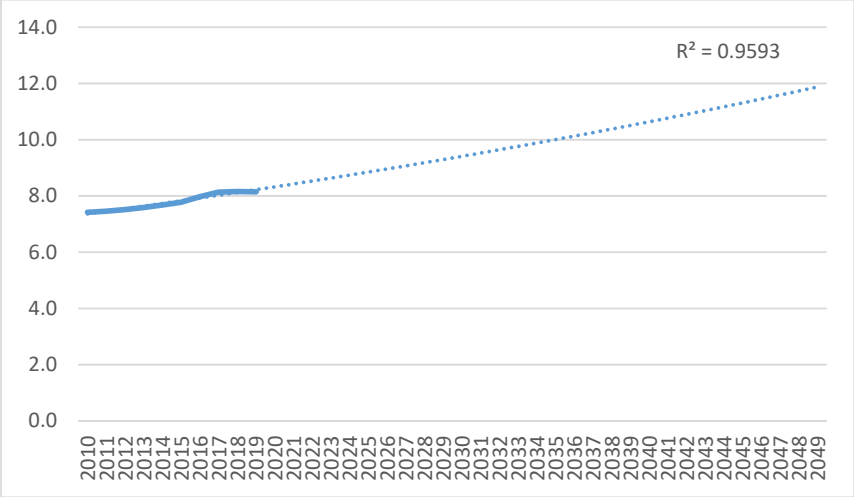

Figure 66: 10 to 14 female cohort cyclists serious injury rate per 100,000

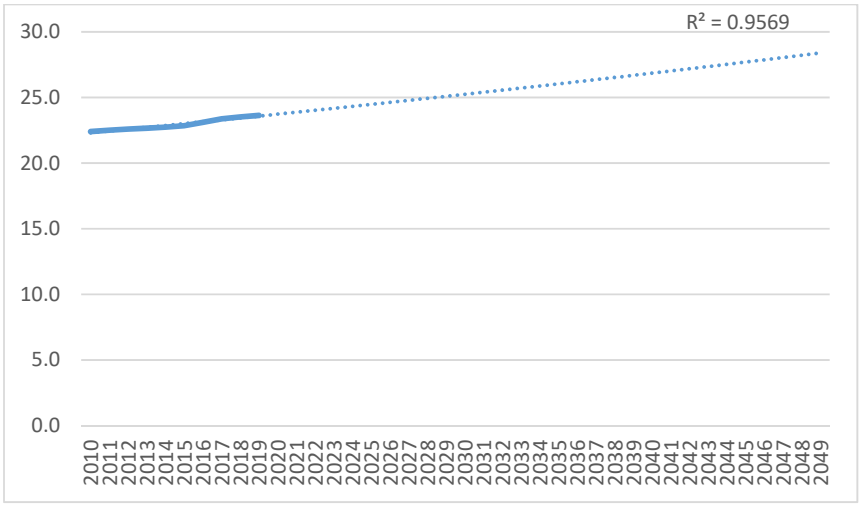

Figure 67: 10 to 14 female cohort motor cyclists serious injury rate per 100,000

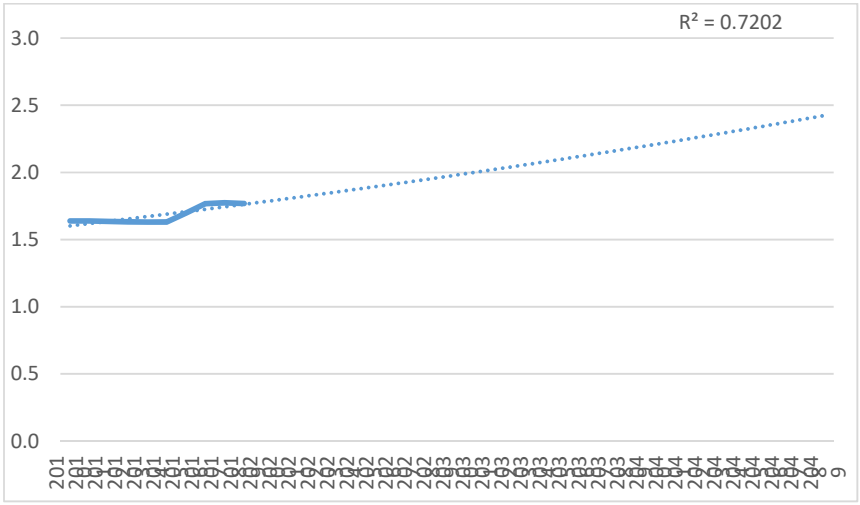

Figure 68: 10 to 14 female cohort motor vehicles serious injury rate per 100,000

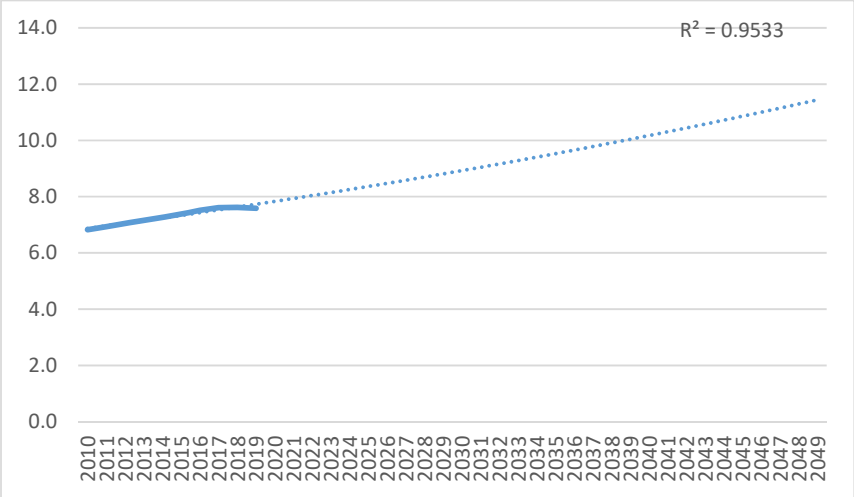

Figure 69: 10 to 14 female cohort other serious injury rate per 100,000

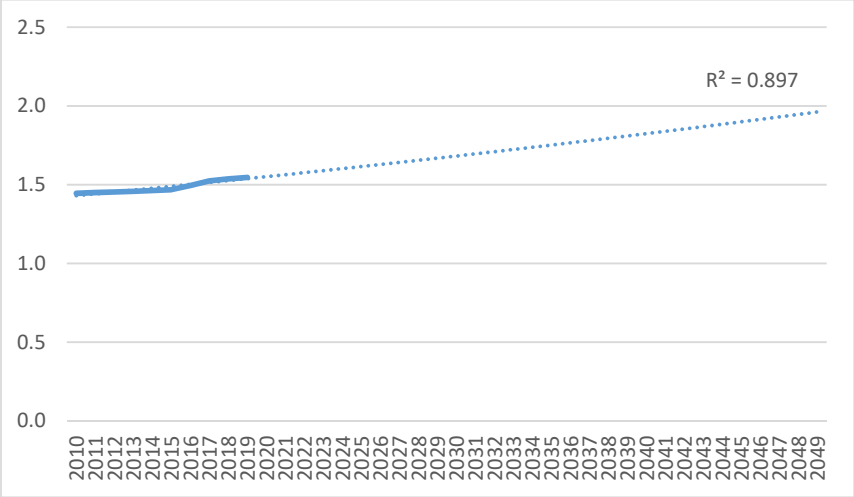

Figure 70: 15 to 19 male cohort pedestrian fatality rate per 100,000

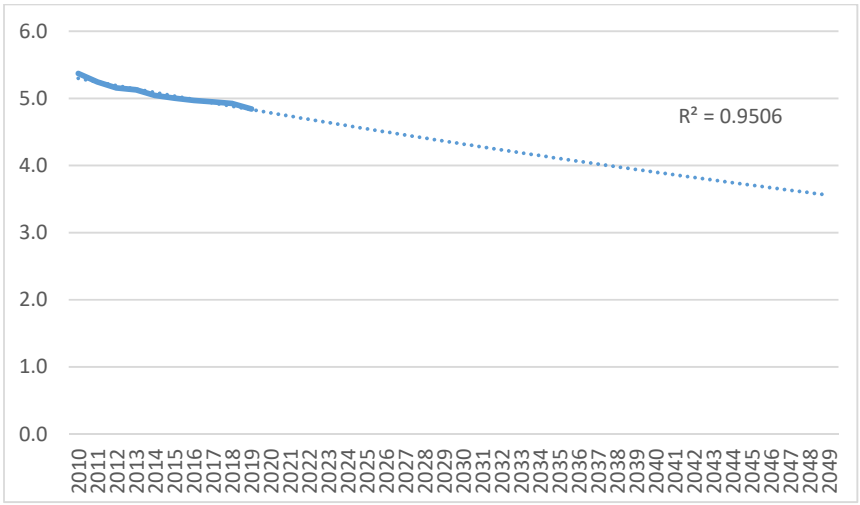

Figure 71: 15 to 19 male cohort cyclists fatality rate per 100,000

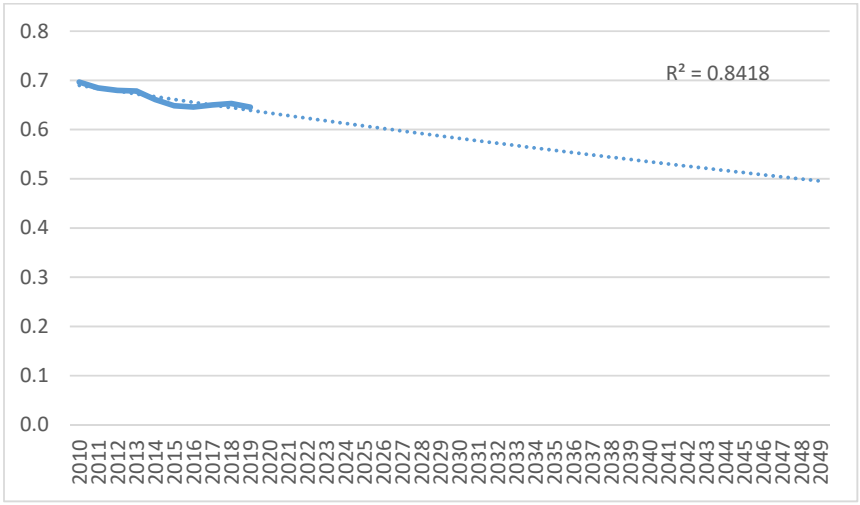

Figure 72: 15 to 19 male cohort motor cyclists fatality rate per 100,000

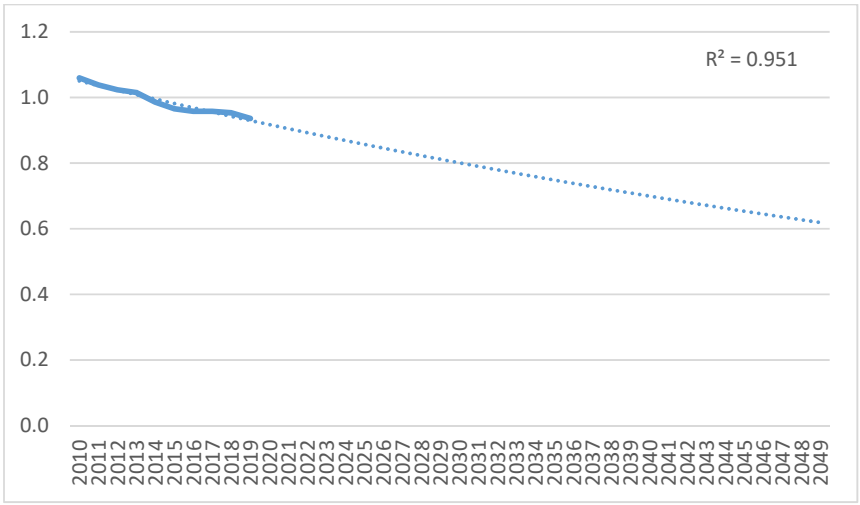

Figure 73: 15 to 19 male cohort motor vehicles fatality rate per 100,000

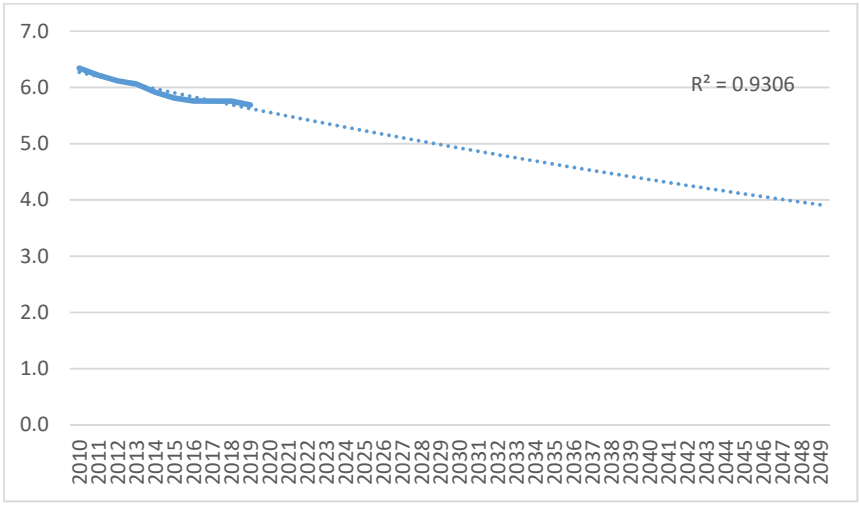

Figure 74: 15 to 19 male cohort other fatality rate per 100,000

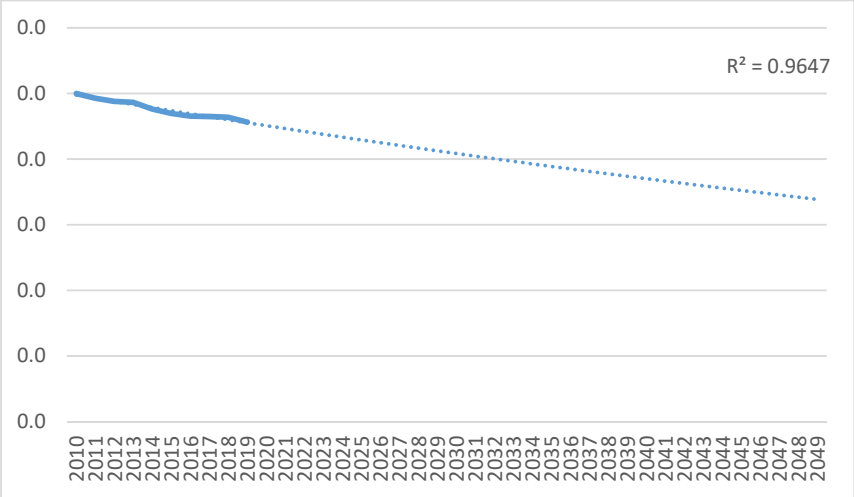

Figure 75: 15 to 19 female cohort pedestrian fatality rate per 100,000

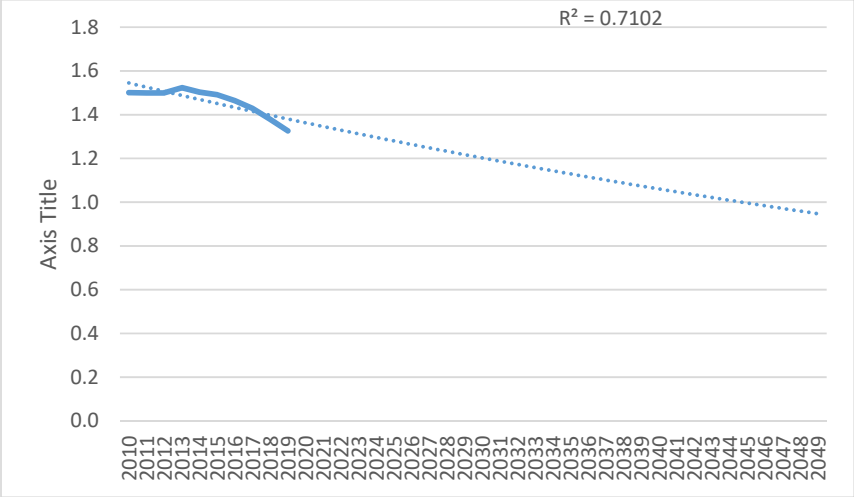

Figure 76: 15 to 19 female cohort cyclists fatality rate per 100,000

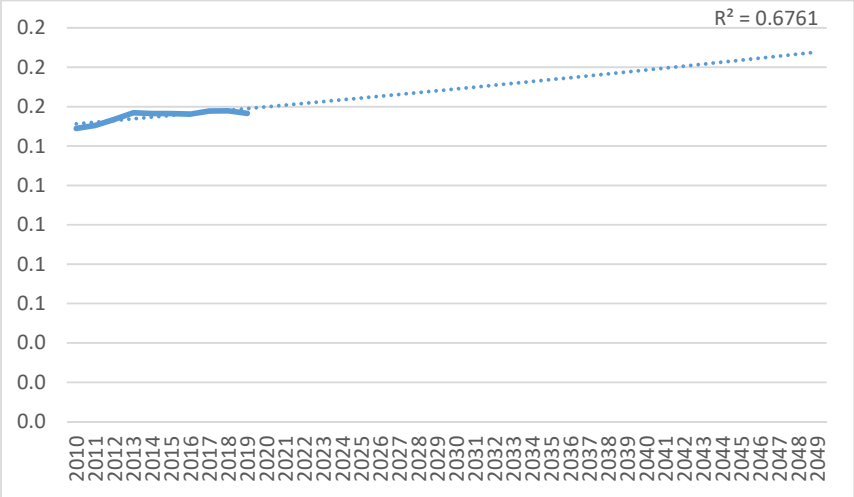

Figure 77: 15 to 19 female cohort motor cyclists fatality rate per 100,000

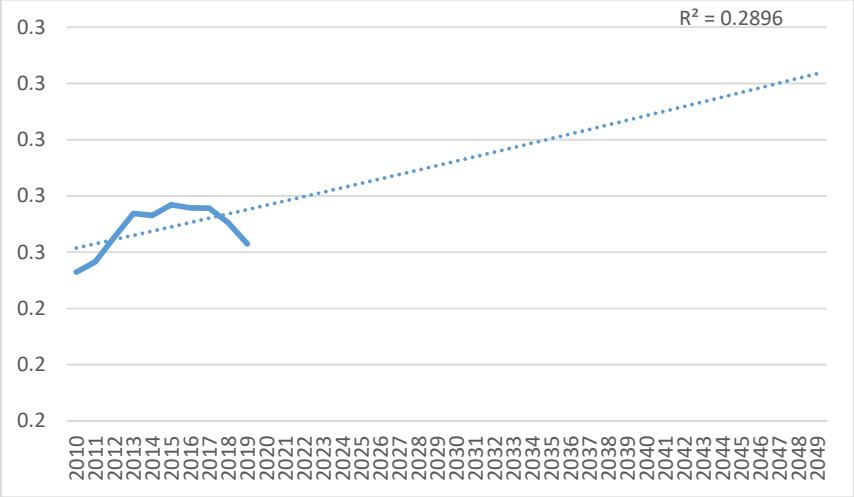

Figure 78: 15 to 19 female cohort motor vehicles fatality rate per 100,000

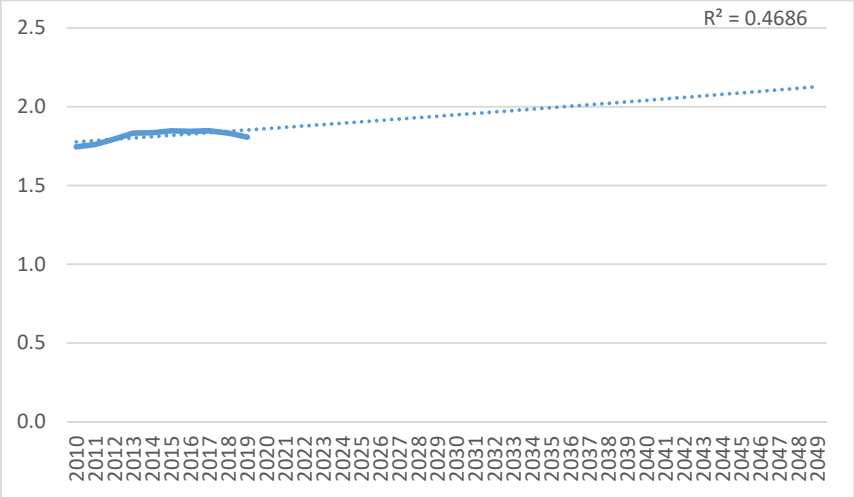

Figure 79: 15 to 19 female cohort other fatality rate per 100,000

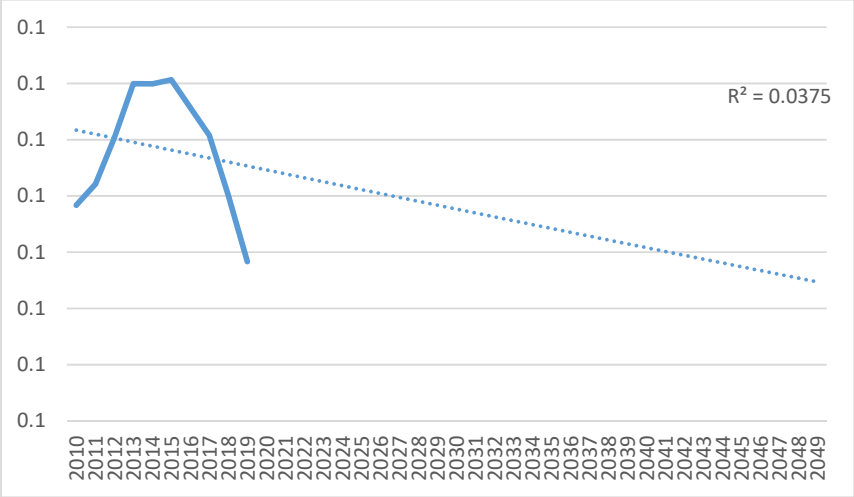

Figure 80: 15 to 19 male cohort pedestrian serious injury rate per 100,000

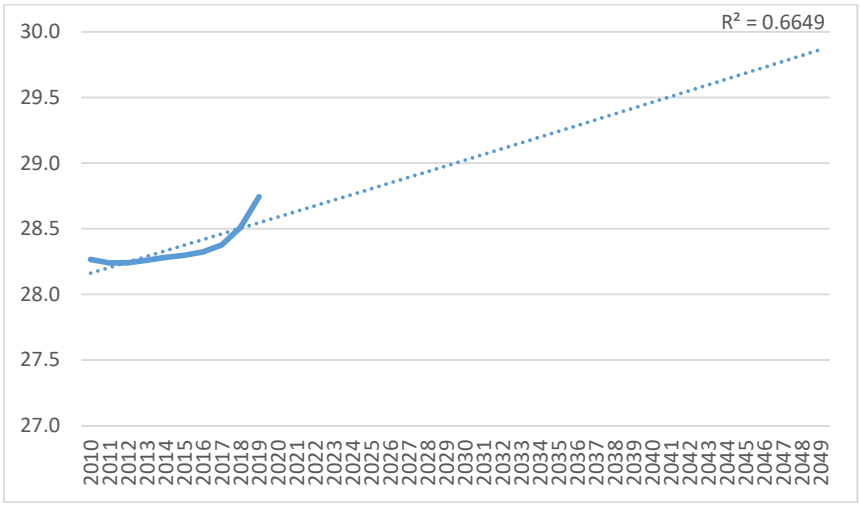

Figure 81: 15 to 19 male cohort cyclists serious injury rate per 100,000

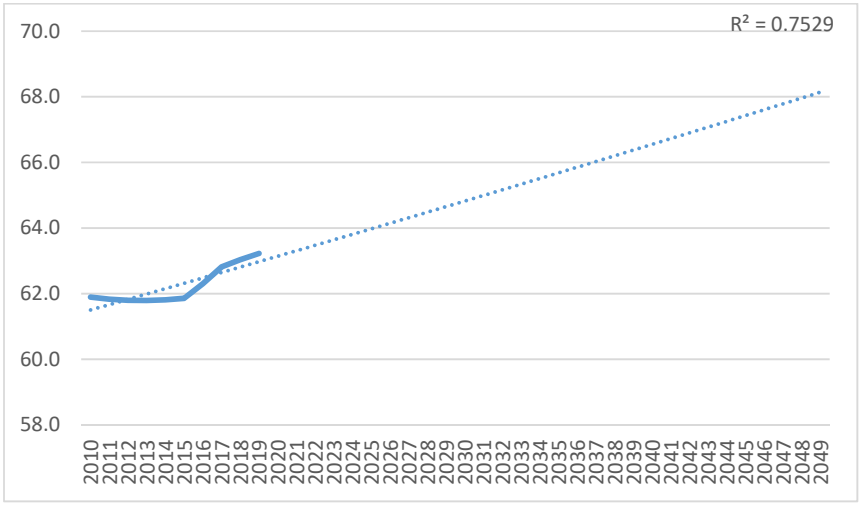

Figure 82: 15 to 19 male cohort motor cyclists serious injury rate per 100,000

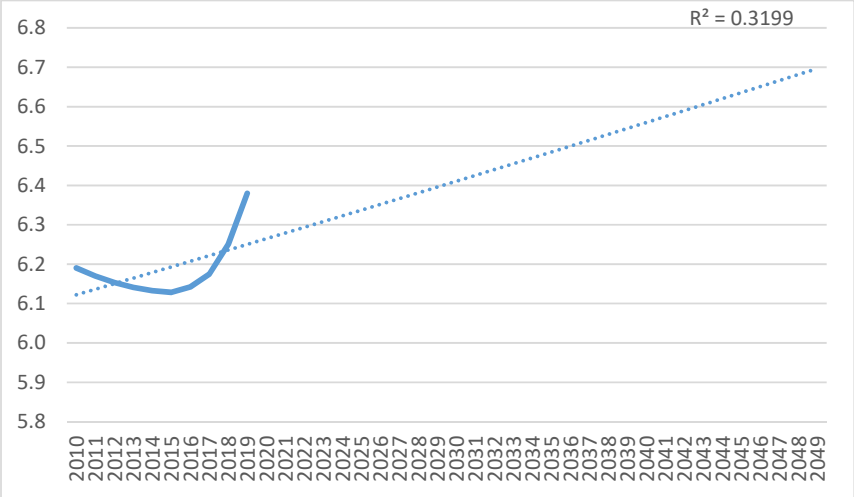

Figure 83: 15 to 19 male cohort motor vehicles serious injury rate per 100,000

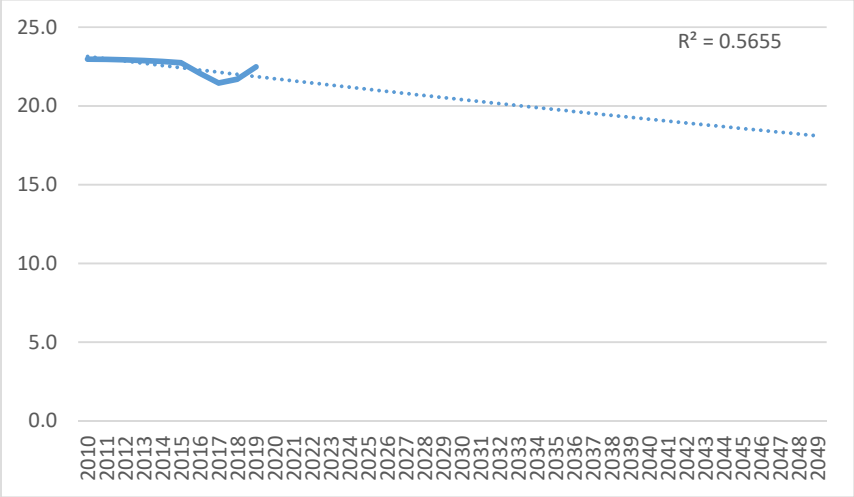

Figure 84: 15 to 19 male cohort other serious injury rate per 100,000

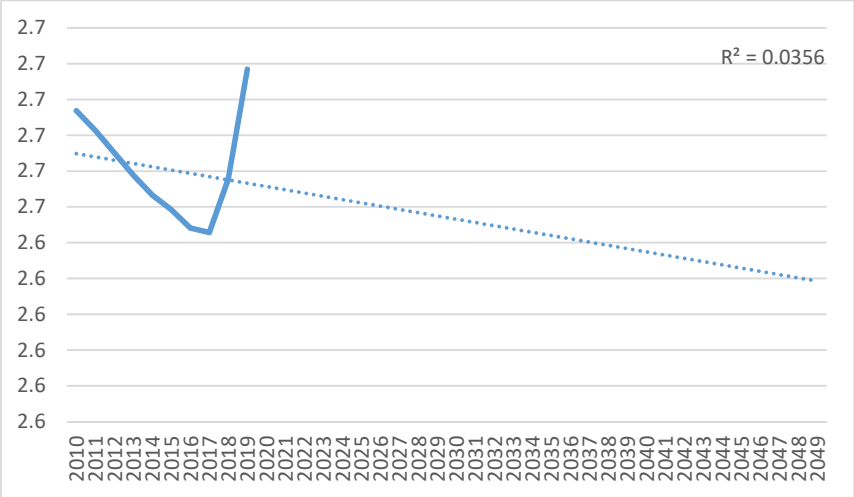

Figure 85: 15 to 19 female cohort pedestrian serious injury rate per 100,000

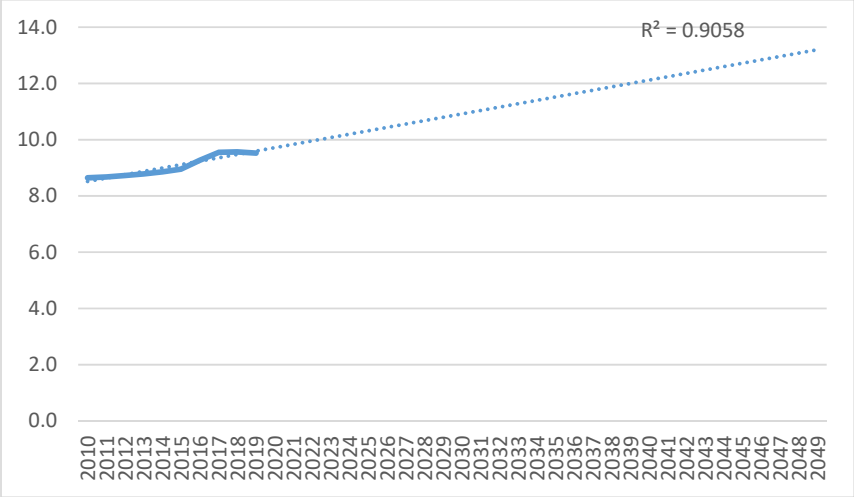

Figure 86: 15 to 19 female cohort cyclists serious injury rate per 100,000

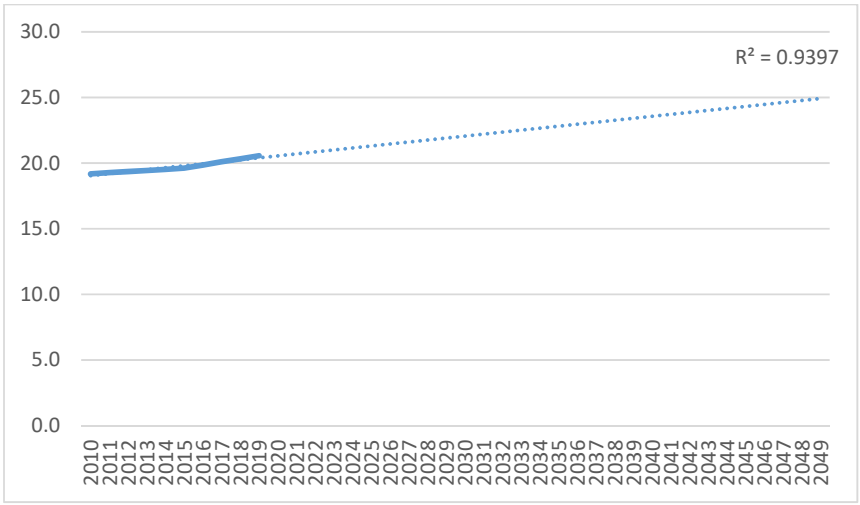

Figure 87: 15 to 19 female cohort motor cyclists serious injury rate per 100,000

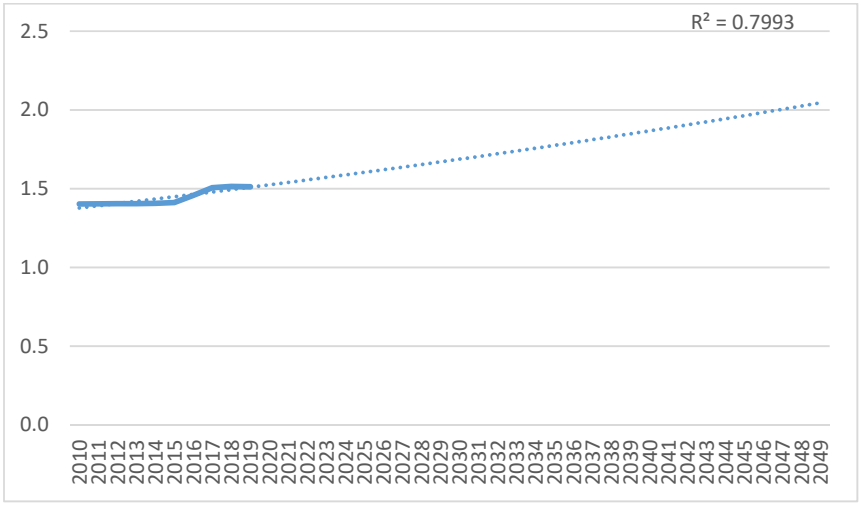

Figure 88: 15 to 19 female cohort motor vehicles serious injury rate per 100,000

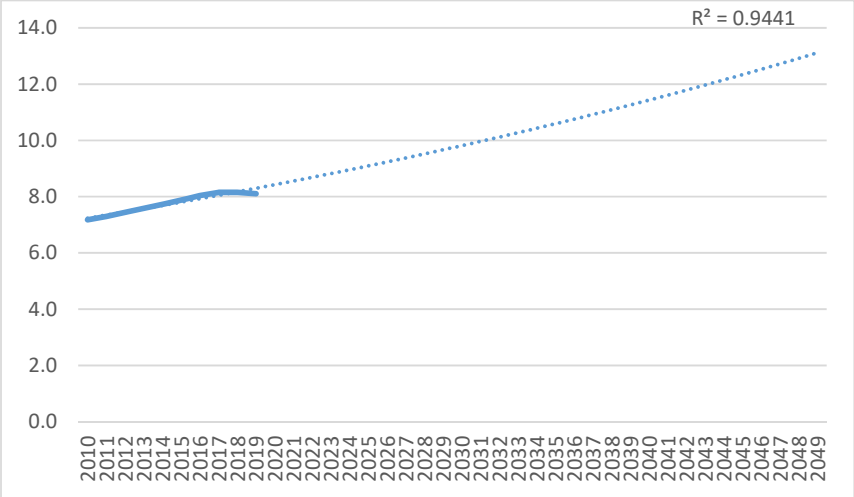

Figure 89: 15 to 19 female cohort other serious injury rate per 100,000

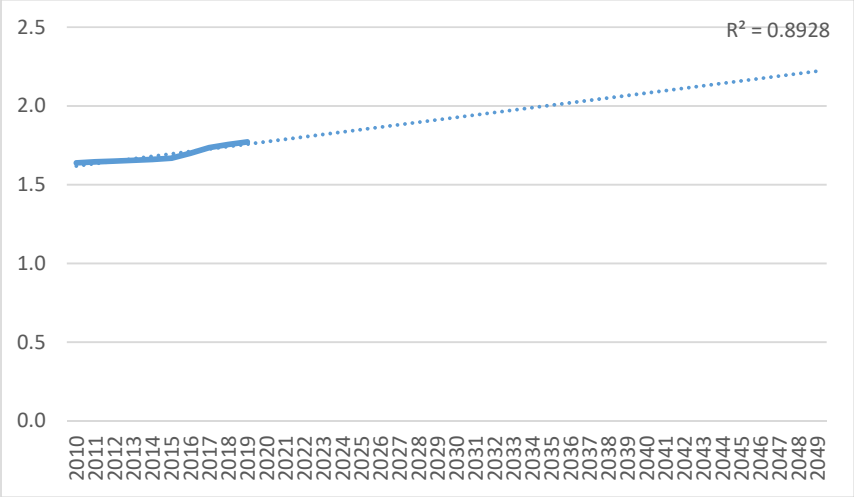

Figure 90: 20 to 24 male cohort pedestrian fatality rate per 100,000

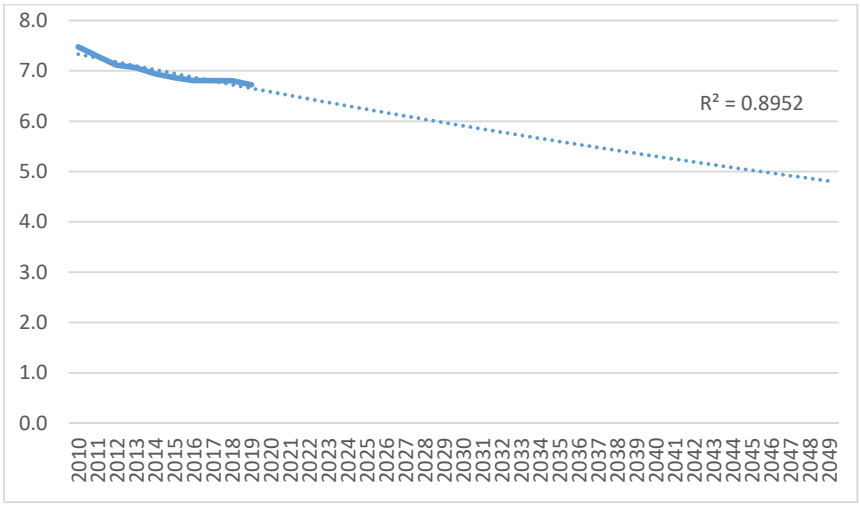

Figure 91: 20 to 24 male cohort cyclists fatality rate per 100,000

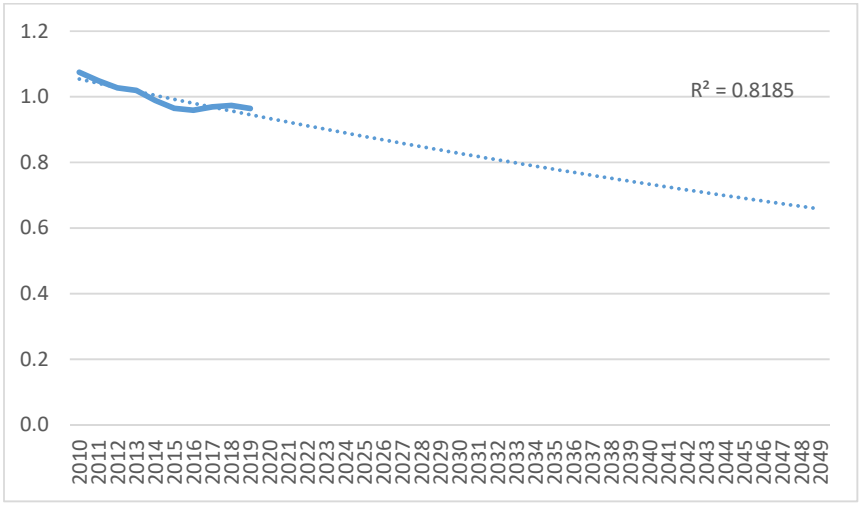

Figure 92: 20 to 24 male cohort motor cyclists fatality rate per 100,000

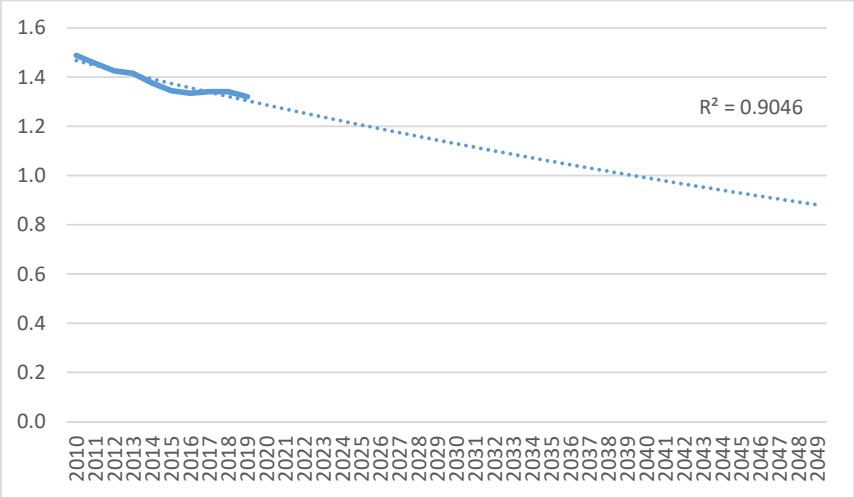

Figure 93: 20 to 24 male cohort motor vehicles fatality rate per 100,000

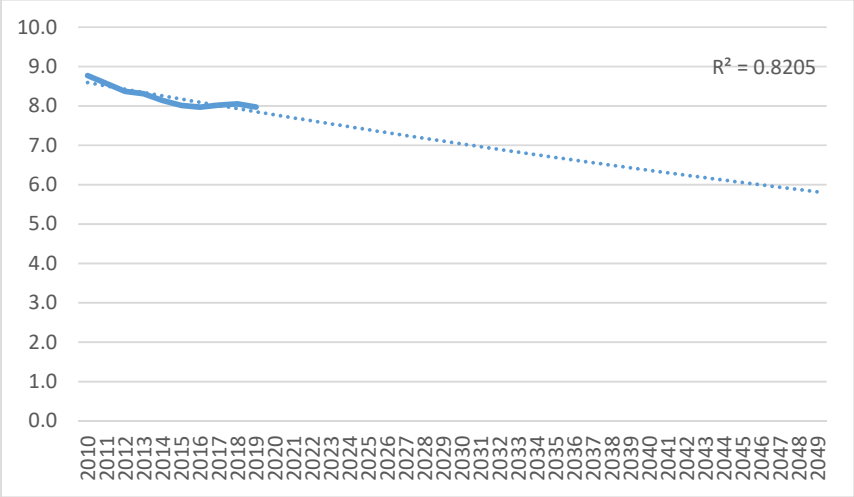

Figure 94: 20 to 24 male cohort other fatality rate per 100,000

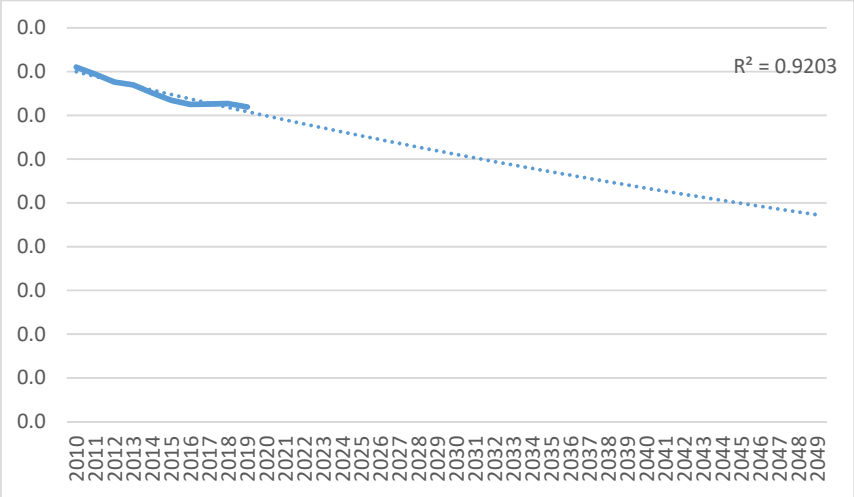

Figure 95: 20 to 24 female cohort pedestrian fatality rate per 100,000

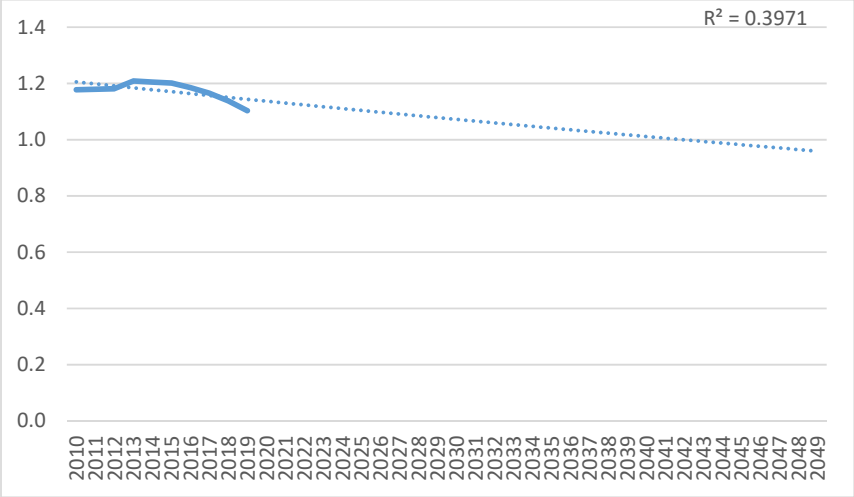

Figure 96: 20 to 24 female cohort cyclists fatality rate per 100,000

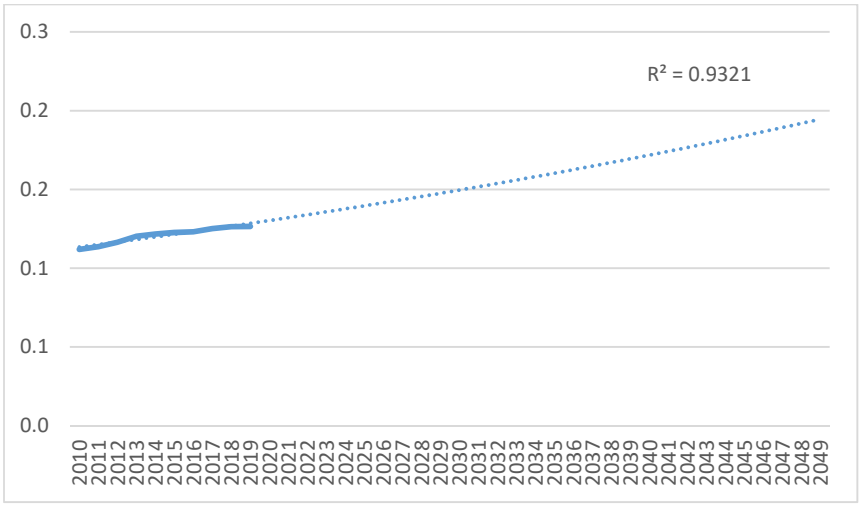

Figure 97: 20 to 24 female cohort motor cyclists fatality rate per 100,000

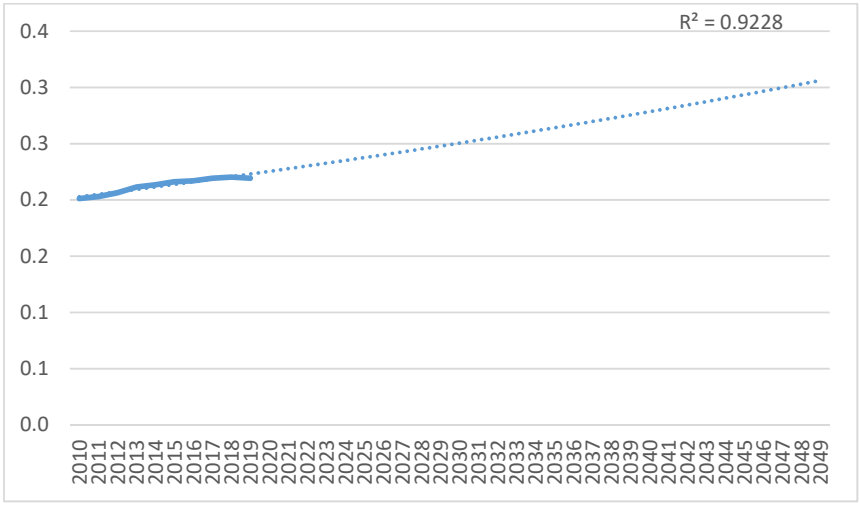

Figure 98: 20 to 24 female cohort motor vehicles fatality rate per 100,000

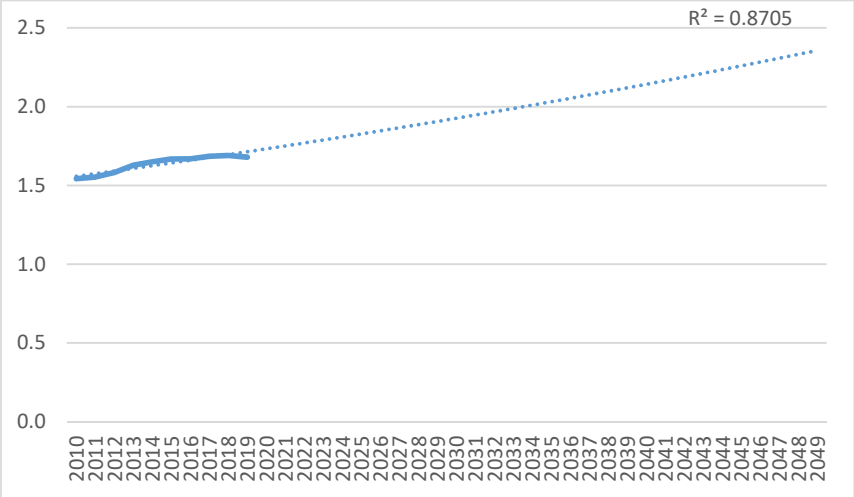

Figure 99: 20 to 24 female cohort other fatality rate per 100,000

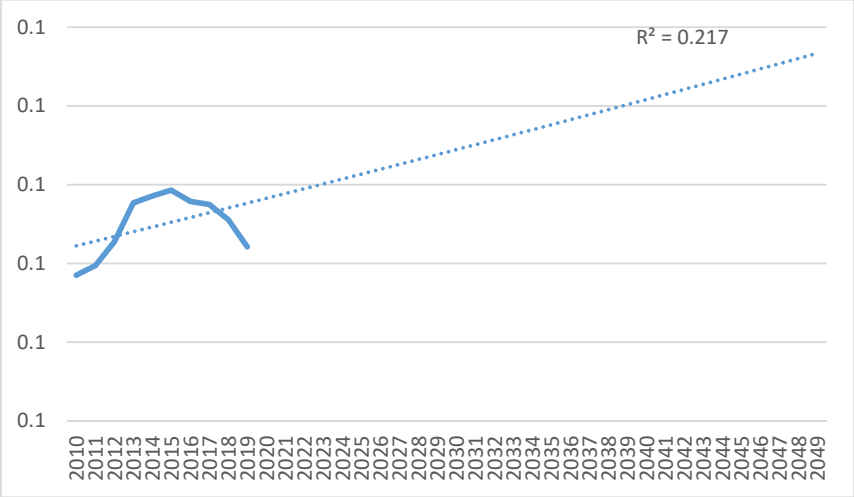

Figure 100: 20 to 24 male cohort pedestrian serious injury rate per 100,000

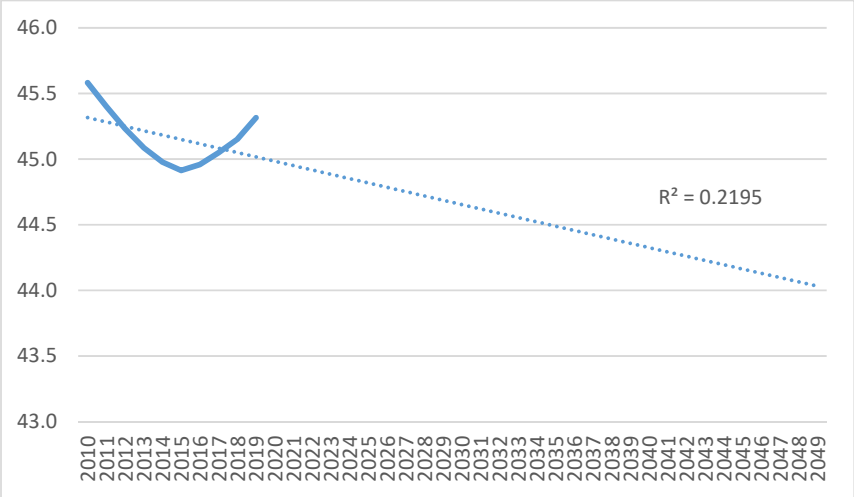

Figure 101: 20 to 24 male cohort cyclists serious injury rate per 100,000

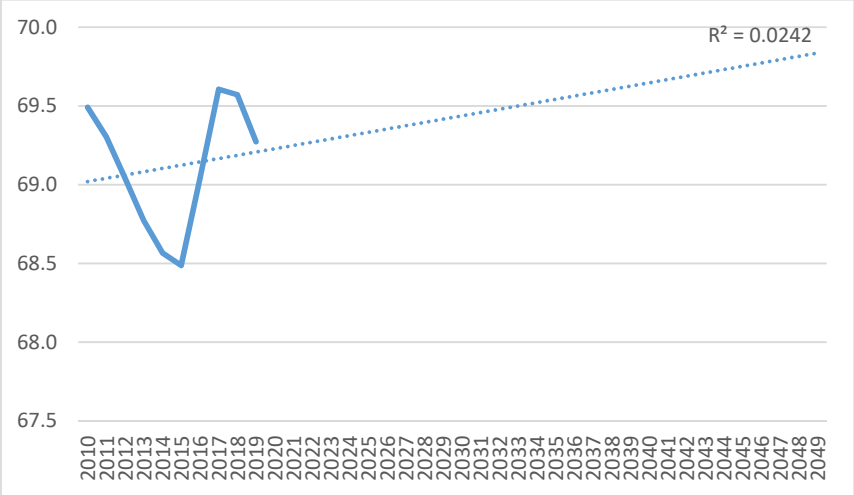

Figure 102: 20 to 24 male cohort motor cyclists serious injury rate per 100,000

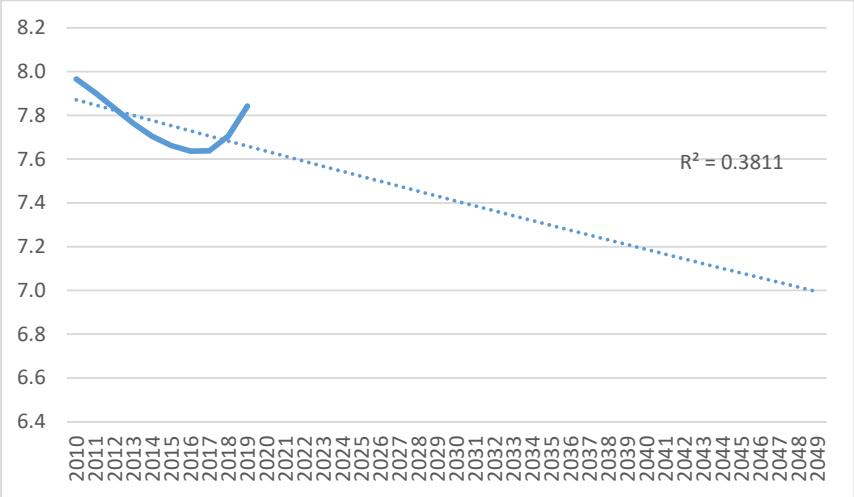

Figure 103: 20 to 24 male cohort motor vehicles serious injury rate per 100,000

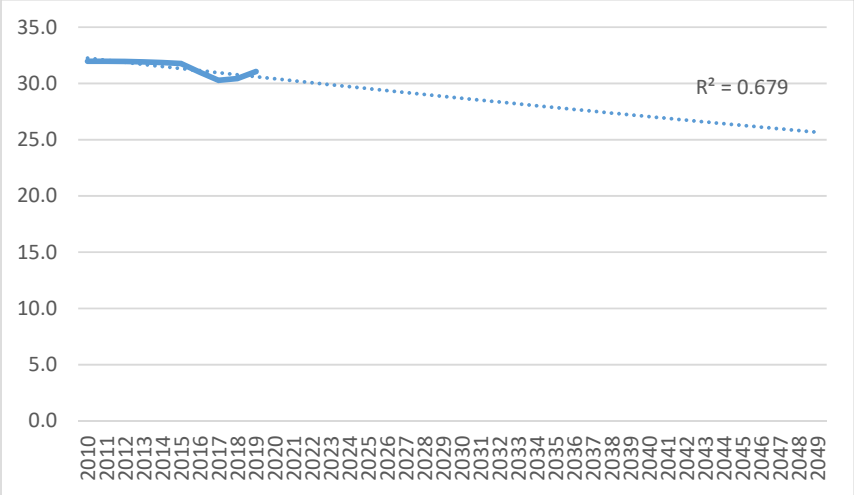

Figure 104: 20 to 24 male cohort other serious injury rate per 100,000

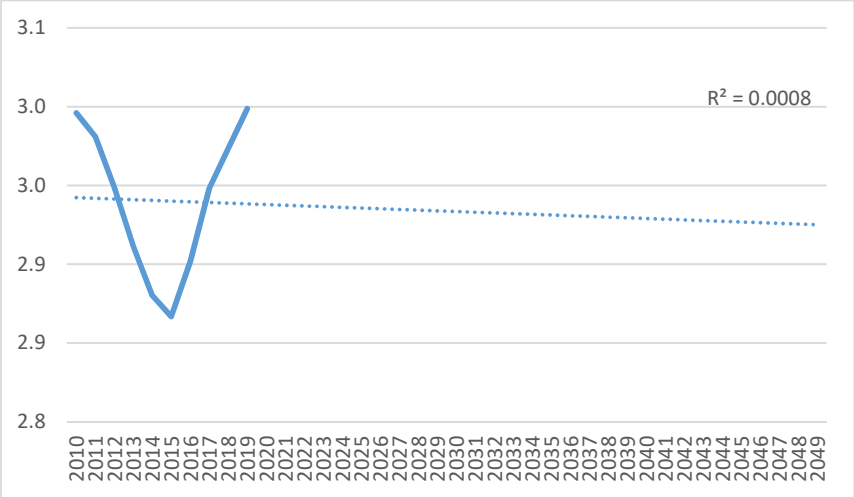

Figure 105: 20 to 24 female cohort pedestrian serious injury rate per 100,000

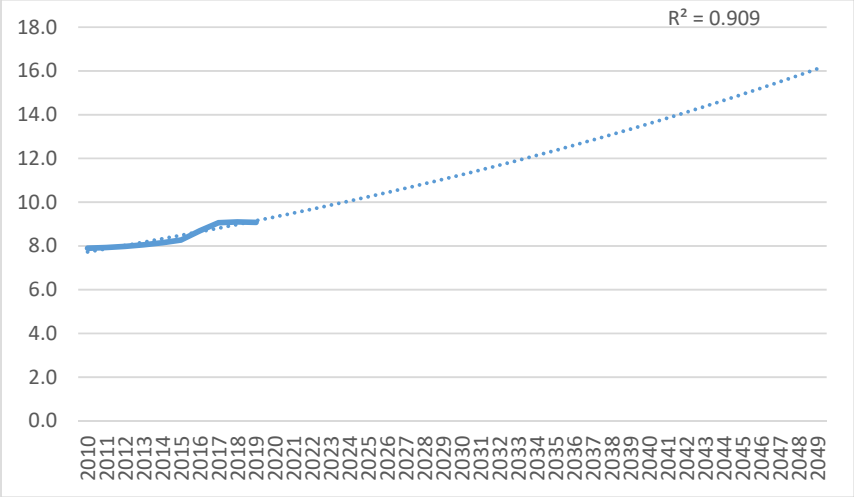

Figure 106: 20 to 24 female cohort cyclists serious injury rate per 100,000

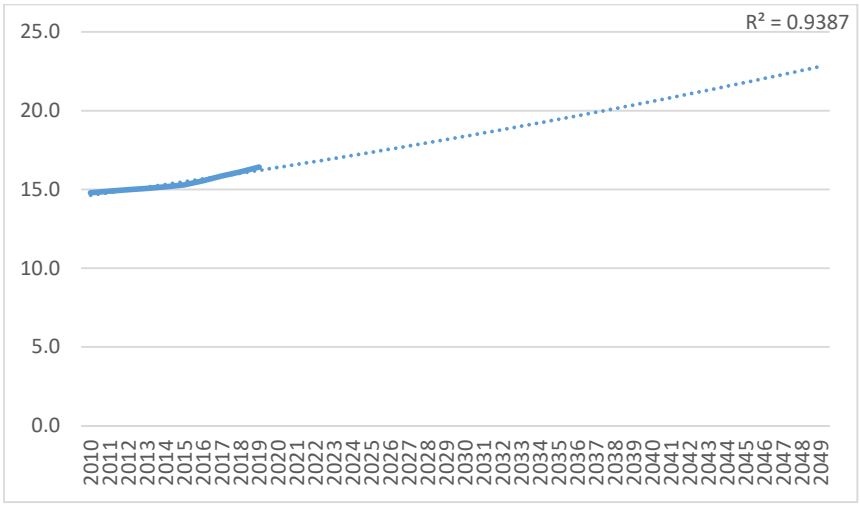

Figure 107: 20 to 24 female cohort motor cyclists serious injury rate per 100,000

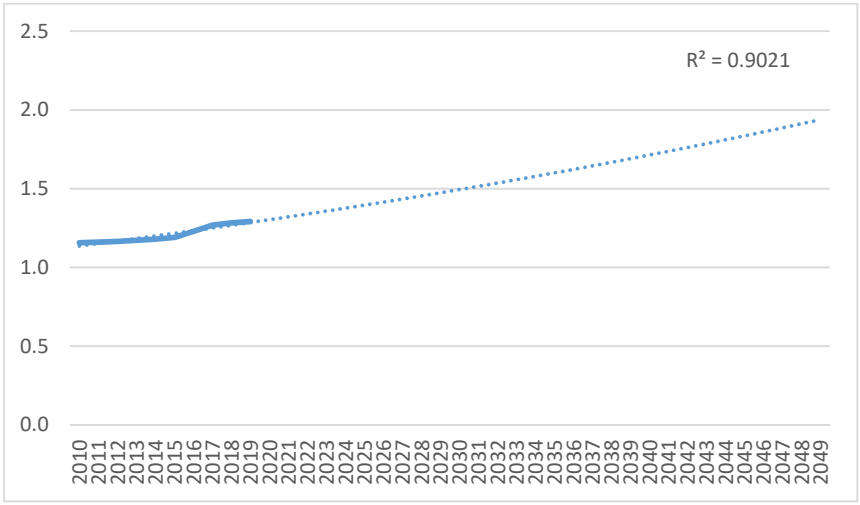

Figure 108: 20 to 24 female cohort motor vehicles serious injury rate per 100,000

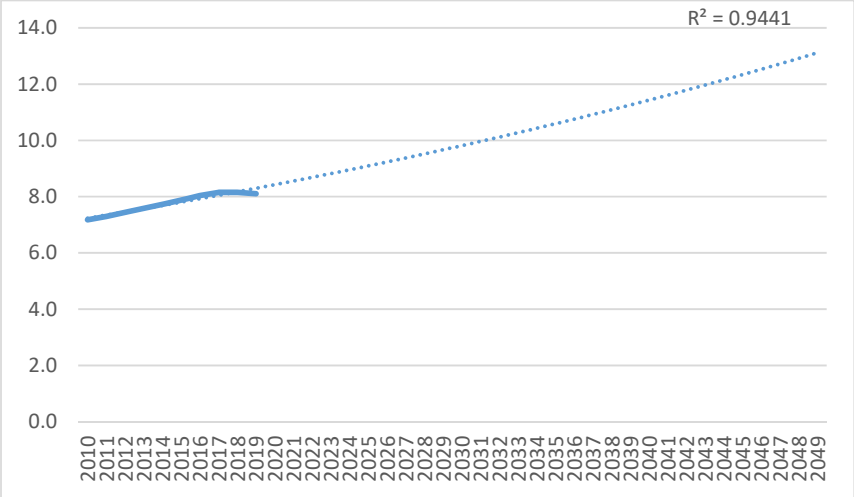

Figure 109: 20 to 24 female cohort other serious injury rate per 100,000