Divis Street Bridge Suicide Deterrent System Project

40245568

MSc Environmental Engineering,

Queen’s University Belfast

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Glossary of Terms

AADT	Annual Average Daily Traffic
DfI	Department for Infrastructure
DMRB	Design Manual for Roads and Bridges
FOI	Freedom of Information
MCHW	Manual of Contract Documents for Highway Works
NHSS	National Highway Sector Schemes
OSNI	Ordnance Survey of Northern Ireland
PHA	Public Health Agency, (Northern Ireland Health and Social Care)
PPR	Participation and the Practice of Rights
PRS(s)	Pedestrian Restraint Systems
PSNI	Police Service of Northern Ireland
SPUI	Single-point Urban Interchange
TD 19/06	Design Manual for Roads and Bridges Volume 2 Section 2 Part 8 - TD 19/06 - Requirement for Road Safety Restraint Systems
VRS(s)	Vehicle Restraint Systems

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1. INTRODUCTION

Problem Description

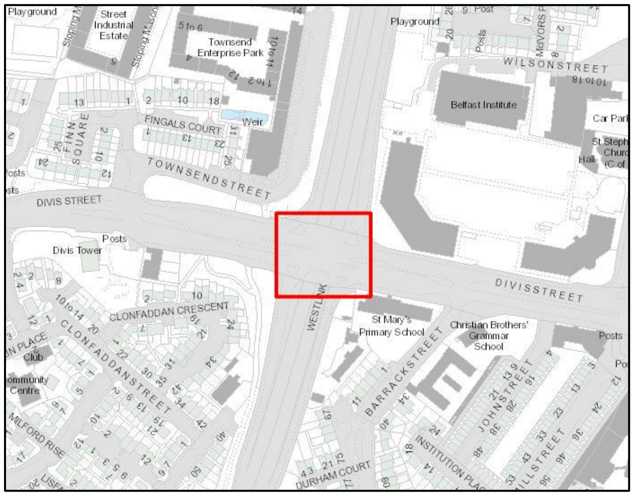


Figure 1 *Project Location (OSNI, 2019)*

Overview

Divis Street Bridge stretches over one of the busiest carriageways in Northern Ireland; the Westlink (A12) corridor, and unfortunately it has become a site of numerous suicide occurrences. Of all the Westlink overbridges, Divis Street Bridge, with a pedestrian restraint system of 1.44m, has the most exposed passage; providing lethal means to troubled individuals. By contrast, parapet height on Grosvenor Bridge is 2.4m, offering much better containment for the public.

Following a fatal incident in 2016, the *Square Cut Punt Crew* group launched a campaign lobbying for the Department for Infrastructure to heighten bridge parapets on Divis Street Bridge. Considerably higher railings, as the ones found on Clifton Street and Grosvenor Bridges, would prevent any future suicidal jumps at the site. The unfortunate event of late 2016 and other failed attempts shown in the records of the Northern Ireland Ambulance Service (NIAS), suggest that the site has a particular appeal to suicidal individuals. In addition, work carried out by the Police Service of Northern Ireland (PSNI) to identify road-related suicide risk areas concluded that the majority of suicides and suicide attempts in Northern Ireland involve bridges, many of which over motorways (Harrison, 2017).

Under Protect Life 2, Northern Ireland's current suicide prevention strategy, the Department for Infrastructure and Public Health Agency have the responsibility to explore measures to restrict access to means at such high-risk locations. A physical barrier would 'buy time' for both the individual – to reconsider their actions, and for emergency services – to attend to the scene in time (Cox et al., 2013). Work is rightfully being carried out on the Foyle Bridge in Derry/Londonderry, and there is enough evidence for a physical barrier to be erected on Divis Street Bridge.

Understanding the Area

Divis Street Bridge is located in the Lower Falls part of West Belfast, an area ranked by the Department for Communities (2019) as the second most deprived area in Northern Ireland. Therefore, with the right conditions for poor mental wellbeing, such places of hardship are associated with the highest rates of suicide (Samaritans, 2018). Five years of research by Black and McKay (2019) discovered that West Belfast's average annual suicide rate of 26 per 100,000 persons between 2012 and 2016 was the second highest in Northern Ireland. At ward level, Lower Falls has a suicide rate three times that of Northern Ireland's average.

Suicide by jumping from public spaces such as bridges is more likely to be carried out by young adults, particularly males, (Beautrais, 2007) and the Falls area has a higher proportion of 16 - 24-year olds than typically found in other wards in Northern Ireland (Department for Communities, 2016). Hence, the bridge is located in the vicinity of groups who are vulnerable to suicidal thoughts. A homeless shelter, The Morning Star House, is also only about a hundred metres down the road.

Technical Setting

According to the FOI documents retrieved by the *Participation and the Practice of Rights* (PPR) organisation, the existing parapet system on Divis Street Bridge comprises of a 1.04-metre-high reinforced concrete wall and a metal rail that sits on top resulting in a total height of 1.44 metres. Detailed specifications of the existing parapet configuration can be found in Chapter 3 – the feasibility study report for the project.

The existing parapets on Divis Street Bridge can easily be scaled, with the concrete base providing a stable foothold for an individual to climb over and take the 8 metre plunge down onto the Westlink carriageway underneath. The substantial drop would likely result in death or severe injuries upon impact.

The current suicide prevention initiative, as highlighted in the FOI documents, aims for a collective ‘corridor’ approach on the Westlink. This includes increased CCTV monitoring and additional training to emergency services personnel on effective procedures when responding to suicide attempts at bridges such as Divis Street Bridge. Hard intervention measures are, however, not part of the current discussion. In alignment with the Square Cut Punt Crew and PPR, this project proposes an upgrade of the existing restraint system on Divis System to prevent suicide attempts by jumping. Restricting access to means would: (1) ‘buy time’ for distressed individuals to reconsider their actions (Cox et al., 2013), (2) avoid traumatising members of the public and (3) secure the site from becoming a ‘suicide magnet’ as Friend (2013) describes that a few successful jumps can be enough to make a site ‘iconic’ and attract more desperate individuals to take the plunge.

Aim and Objectives

PPR initially presented the project in order to gain an understanding of the Department for Infrastructure’s position, as a public service body, in preventing suicide attempts on Northern Ireland’s road bridges, particularly Divis Street Bridge in Belfast. Some of the questions relating to the project, within the Department’s apparent field of responsibility, that the group raised include: (1) “What criteria does the Department use to identify roadway sites ‘as particularly problematic’?”, (2) “What are the national standards in operation governing the height requirements for motorway and dual carriageway bridge parapets?”, and (3) “Explanation for the lack of uniformity of parapets on the Westlink’s overbridges. For instance, why Divis Street Bridge’s railings are 1 metre lower than Grosvenor Bridge railings?”.

Ultimately, the aim of the campaign was to have Divis Street Bridge's existing restraint system upgraded to prevent suicidal jumps in the future. Similarly, this project aims to **provide a structural solution to deter suicide by jumping from Divis Street Bridge**. Project boundaries were set by the following objectives:

i. To determine national standards and guidance in operation governing the height requirements for motorway and dual carriageway bridge parapets.
ii. Consideration of the Westlink corridor in the context of bridge safety.
iii. To provide details of any road bridges in Northern Ireland and the rest of the world where structural intervention has been taken as a suicide prevention measure.
iv. To identify feasible structural solutions to deter suicidal jumps from Divis Street Bridge.

2. BACKGROUND

Standards and Guidelines

All bridges that the public has access to are required to incorporate a pedestrian restraint system (or simply parapet) into the design (The Highways Agency, 2006).

A pedestrian restraint system (PRS) is a safety barrier erected on the edge of a structure where there is a vertical drop, such as a bridge, to protect users from falling off.

The current technical approval schedule (April 2019) for the design of highway structures, *Schedule of Documents Relating to Design of Highway Bridges and Structures*, requires the delivery of highway parapets to conform to the requirements and guidance set out in the following guides:

i. DMRB Volume 2 Section 2 Part 8 - Requirement for Road Safety Restraint Systems (TD 19/06),
ii. Interim Advice Note 97/07 - Assessment and upgrading of existing parapets, and
iii. BS 7818:1995 - Specification for pedestrian restraint systems in metal.

Much of the guidance available to the highway designer focuses on road restraint systems for the containment of errant vehicles. As a result, the design process for PRSs is not supported by a comprehensive risk assessment as is the case for Vehicle Restraint Systems (VRSs). BS 7818, the de facto standard for the design of pedestrian parapets, specifies structural requirements such as deflection and design loads, ensuring pedestrian parapets are robust instead of maximising their functionality. The minimum height for a bridge parapet, in accordance with BS 7818, is 1.15m for pedestrians and 1.4m for cyclists. There is no evidence where these height requirements were derived from.

However, much of the design guidance, including The Highways Agency (2006), clearly recognise the importance of a site-specific risk assessment during the design phase of a Pedestrian Restraint System. When questions such as, for instance, “how high is the drop down onto the motorway below?" are addressed during the design process, key parameters that include parapet height can be adjusted to appropriate specifications that would effectively safeguard the public. The Department for Infrastructure's one-size-fits-all approach has led to under-engineering in the case of Divis Street Bridge.

Therefore, although the pedestrian restraint system on the Divis Street Bridge complies with the current 'moderate' regulations, it certainly is not a form of good engineering practice.

Beyond the standards, it is not uncommon for physical suicide deterrent systems, to be erected where a site is identified as of particular risk. Under these circumstances, the responsibility to explore structural intervention options that deter suicidal jumps from Northern Ireland's bridges falls on the Department for Infrastructure as set out by the Department of Health (2016). There is no evidence of the DfI conducting such work. However, parapet improvement schemes have been undertaken in other parts of the country and abroad following successful campaigns as the *Square Cut Punt Crew's*. In all the case studies discussed below, the projects have fulfilled their function in preventing suicides at the respective sites.

Case Studies

United Kingdom

I. Clifton Suspension Bridge, Bristol

Clifton Suspension Bridge is a major road bridge spanning 75 metres over the Avon Gorge in Bristol. The bridge was opened in 1864 and suicide prevention barriers were only erected in 1998. The barriers shown in *Figure 3* below, which stand in front of the original restraint system, are comprised of a 1.5-metre-high inclined grid fencing and five parallel taut steel wires with a further inward curve that raise the total height of the barrier to 2 metres above the deck

Bennewith, Nowers, and Gunnell (2007, 2010) reported that the 1998 fencing installation on the bridge had reduced suicide fatalities at the site by half, from 41 in the five years prior to the intervention, to just 20 in the five years that followed. Additional soft measures were also introduced at the site and in the subsequent years, numbers drastically reduced. These measures including CCTV cameras, staff to monitor the CCTV feed and patrol the site, as well as posters with *Samaritans* helpline (Public Health England, 2015). However, the lack of barriers on the buttress wall at either end of the bridge, which Bennewith, Nowers and Gunnell (2010) attributed to 'architectural reasons', has left those parts of the bridge at an even higher risk. Leaving the ends exposed simply means they could be skirted around, thereby providing the only access to means at the site.

Figure 3 *Barriers along the Clifton Suspension Bridge, Bristol (Jaggery 2012)*

Figure 2 *Archway Bridge's anti-suicide fencing (WHPARA, 2019)*

II. Archway Bridge, London

Archway Bridge lies over Hornsey Lane in North London and regular suicidal jumps from the bridge resulted in the informal 'suicide bridge' tag being associated with the site. Following years of design modifications and bureaucratic objections from conservationists, building consent was granted by Islington and Haringey Councils in 2018 for the installation of anti-suicide barriers. The works were completed in the summer of 2019 and can be seen in *Figure 2* above.

The main element of the barrier is the 3.3-metre-high stainless-steel fencing erected on the inside of the original parapets. A CCTV system installed in 2016 would also form part of the anti-suicide measurements (Islington Council, 2018), having proved ineffective on its own. Unlike on the Clifton Suspension Bridge, the project ensured a spiked anti-climb mesh at the ends of the bridge would prevent potential victims climbing over at these points.

III. Foyle Bridge, Derry/Londonderry

Since 1984, the Derry/Londonderry's Foyle Bridge has been a site of over 300 suicide attempts, 90 fatalities, and 2000 individuals being talked down from taking the plunge (Mandemaker, 2014).'Our future Foyle' is a collaborative project between Public Health Agency (Northern Ireland) and The Royal College of Art's Helen Hamlyn Centre for Design, which aims to address the mental health concerns at the site. The project is part of a wider regeneration plan to transform the area around the River Foyle, including the Foyle Bridge.

The proposed measures along the bridge involve: (1) art and cultural installations named the 'Foyle bubbles' and (2) the 'Foyle Reeds' - a direct structural engineering solution. Foyle Reeds will comprise of 12,000 aluminium reeds stretching the entire 800 metre span of the bridge at an average height of 2.5 metres (Spencer and Alwani, 2018). The structure would be extremely difficult to climb as it will not have any footholds or fingerholds as shown in *Figure 4* and *5* below. LED lighting will also be embedded into the barrier system and it is proposed that smart technology would enable members of the community to adopt a reed and illuminate it for any special occasions.

Unlike traditional anti-suicide barriers which can create a sense of tragedy, Foyle Bridge's proposed interactive sculptural barrier is unimposing whilst still creating a less exposed passage. The design aims to disassociate the barrier from the negativity of suicidal jumps.

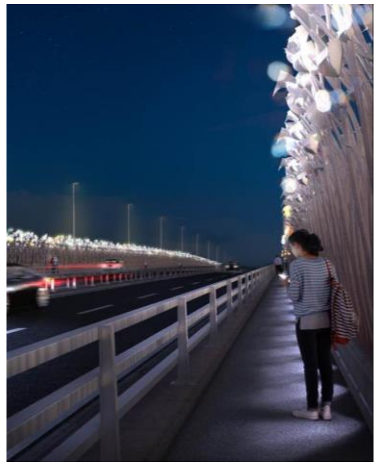


Figure 4 *Proposed sculptural barrier on the Foyle Bridge.*

Figure 5 *Individual Reed Design (Spencer and Alwani, 2018)*

Rest of the world

IV. Grafton Bridge, Auckland, New Zealand

The original anti-suicide mesh screen on Auckland's Grafton Bridge was taken down in 1996 due to, according to Beautrais *et al*. (2009), complaints regarding the imposing nature of the barrier. Unfortunately, a fivefold increase in the number of suicides from the bridge followed and so, eventually, barriers were reinstalled at the site in 2003 (Olson, 2014).

The new suicide deterrent system, constructed from curved plexiglass panels (*Figure 7*), makes it difficult for one to climb along the concrete balustrade. As a result, no fatalities have yet resulted from jumping since its installation.

***Figure 7** Mesh Screens along the Grafton Bridge in 1979 (Karangahape Road Business Association, 2009)*

***Figure 6** Current barrier system on the Grafton Bridge*

V. Bloor Street Viaduct, Toronto, Canada

Toronto’s 500-metre-long Bloor Street Viaduct had been a site of 480 successful suicides before the 5-metre-high *Luminous Veil* barrier was erected in 2003 (Sinyor et al., 2010). With a somewhat similar form to the Grafton Bridge’s barriers, the Luminous Veil consists of inward tilting panels, but instead of tempered glass they are made of steel. Up to 9,000 closely spaced vertical steel rods stretch down from steel plate beams 5 metres above the edge of the deck on the inside of the existing parapets on both sides of the Bloor Street Viaduct (Polo, 2004). Providing the main structural support are angled hollow steel sections attached to the existing exterior framework of the bridge, as shown in *Figures 8* and *9* below.

Hundreds of blue light-emitting LED luminaires illuminate the structure all year round at night-time, creating what is more of a landmark than a suicide barrier. In addition, blue lighting is believed to accelerate relaxation in times of stress and installation on some train platforms in Japan resulted in 84% decrease in the number of suicides (Matsubayashi, Sawada and Ueda, 2013). Since the Luminous Veil was put up, no successful jumps from the site have been reported (Olson, 2014).

Figure 8 *The Luminous Veil, Bloor Street Viaduct, Toronto (Polo, 2004)*

Figure 9 *The Luminous Veil at night (XZZ, 2015)*

Review

The effectiveness of suicide prevention by engineering means is not up for debate and yet there's always a group of people opposed to them. Objections to hard interventions vary from technical complexities that come with the construction of barriers on existing structures to cost related arguments. Another case of opposition is the absurd idea, explained by Sinyor *et al*. (2010), that suicide barriers cannot prevent a person from using other means such as alternative cliffs to jump off from. Suicide attempts in public places usually involve the lives of others and therefore, can cause psychological trauma to members of the public who witness such horrific events. For this reason alone, physical barriers are worth the expense to avert suicides from these sites.

The design of a suicide barrier is shaped by various factors. Iconic sites tend to prioritise appearance so as to minimise visual harm. Hence why the idea of nets has been adopted on San Francisco's Golden State Bridge and various bridges in Ithaca, New York. The reason being; since installation is on a horizontal plane, the nets would be unnoticeable from the line of sight of bypassers, meaning less visual harm to the particular area (Hemmer, Meier and Reisch, 2017).

Lastly, physical suicide barriers also incorporate soft prevention measures into the design to help secure the site. These can be unique to the site just as Ithaca's Stone Arch Bridge has been fitted with sensors to assist in determining if a person is caught in the safety nets.

3. PROJECT APPROACH

Project Scope

The aim of the project is to present an engineering solution that would deter suicide attempts from Divis Street Bridge in Belfast. The report follows standard procedures for civil engineering work in the UK. This section of the report explains the working process of the project, following standard practice for civil engineering projects in the UK as detailed by the Institution of Civil Engineers (2016).

Design work would focus on producing adequate drawings and specifications for the proposed physical suicide barrier. Calculations including structural analysis have not been included as part of the project. However, engineering judgement has been applied to ensure the proposed design does not have any fatal flaws.

The project structure is as follows:

Chapter 1 outlines the problem at Divis Street Bridge and the need for this project.

Chapter 2 reviews standards governing the requirements for bridge parapets, and details case studies of structural intervention measures in the UK and abroad.

Chapter 4 provides details of the existing conditions at Divis Street Bridge and considerations that would be taken into account during design.

Chapter 5 presents the project alternatives and **Chapter 6** details the final suicide barrier design proposal.

Design Process

Feasibility Study

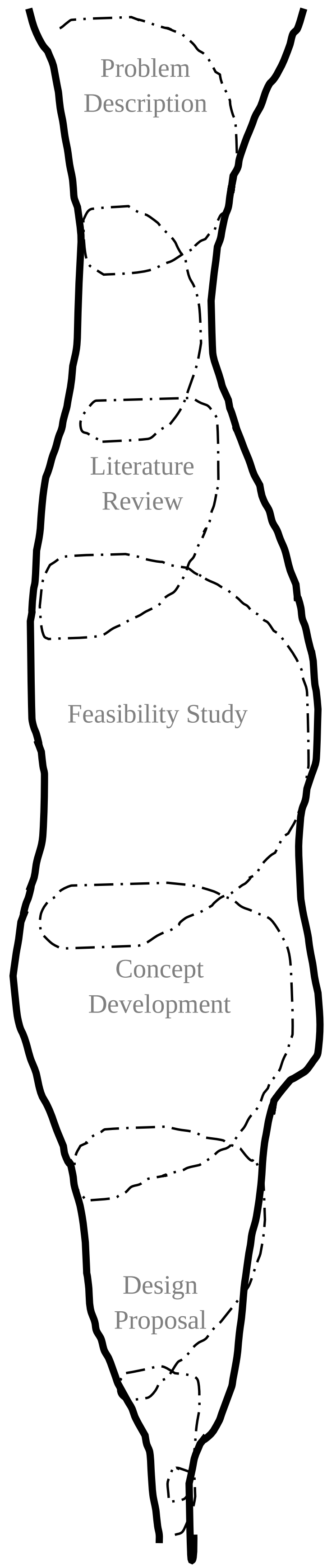
The feasibility study would determine project boundaries through a site investigation, and review of statutory regulations and other factors such as technical constraints. This phase would ultimately establish the baseline for a successful design, i.e. design criteria.

Concept Development

Once the project boundaries have been drawn up, several alternatives would be presented in conceptual form and with sufficient details for screening to be carried out towards an optimal design choice. No less than three conceptual models would be developed in Autodesk's Revit. In addition, a '*do nothing*' scenario would also be considered to demonstrate the consequences of maintaining the status quo (Institution of Civil Engineers, 2016).

Design Proposal

The final proposal, ranked the highest by the evaluation matrix, would be developed further in greater detail within AutoCAD. Technical drawings of the proposed barrier and descriptions of the key design elements, including soft measures, would be presented in the final chapter of the project.



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4. FEASIBILITY STUDY

Scope

The project's feasibility study was conducted, for the most part, through a desktop study utilising OSNI resources and Google Earth. A site walkover was also completed on 09/07/19. This phase was necessary to the project in order to assess existing conditions and identify technical constraints. Once completed, the gathered information would be utilised to establish design criteria that shape the development of technically feasible design solutions.

Consideration was also given to regulatory requirements such as listed building consent with which the final barrier proposal must comply with. Construction schedule and project funding were the other limiting factors.

Site Investigation

Site Description

The project site, Divis Street Bridge, is situated in the Lower Falls area of West Belfast, spanning approximately 55 metres over the A12 Westlink dual carriageway. The bridge forms a single point diamond interchange, providing full access to and from the Westlink. *Figure 11* below shows the project's site boundaries. The 1.44-metres-high parapets in question lie along the outer edges of the pavement strips on Divis Street Bridge, serving as the main barrier between the pedestrian on foot and the drop down onto the Westlink. Figures below show existing conditions, whilst *Figures 12* and 13 provide details of the current state of the existing parapet system that is proposed to be upgraded.

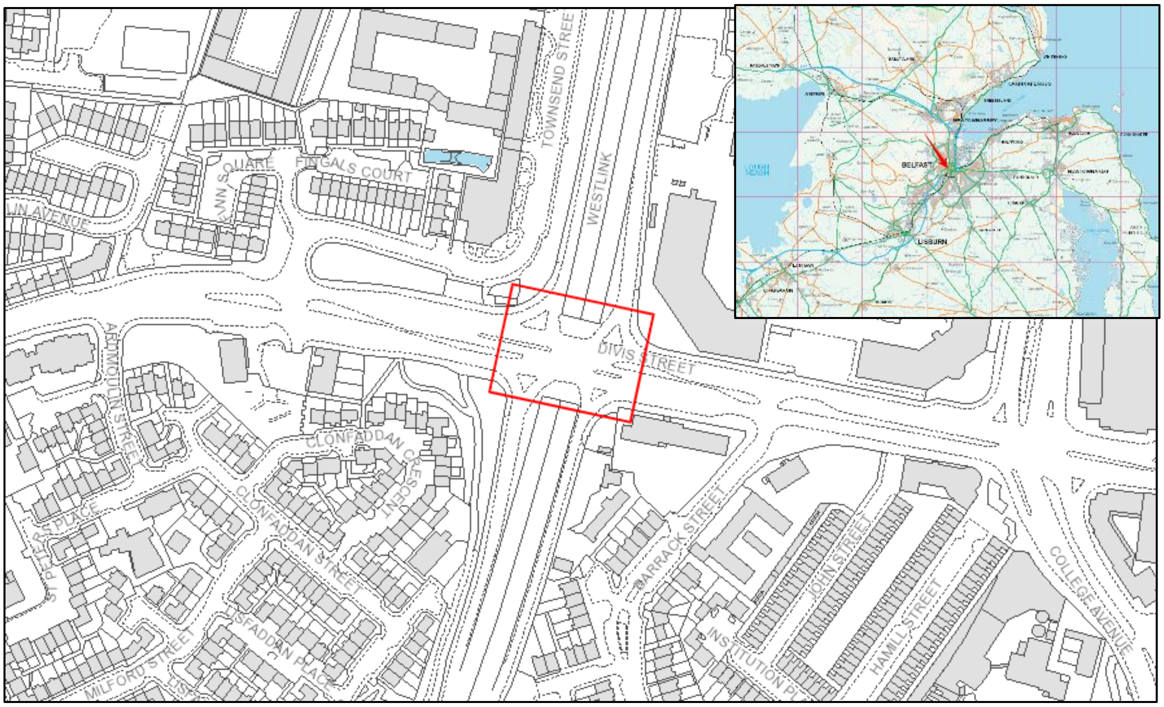

Figure 11 *Project location (OSNI, 2019)*

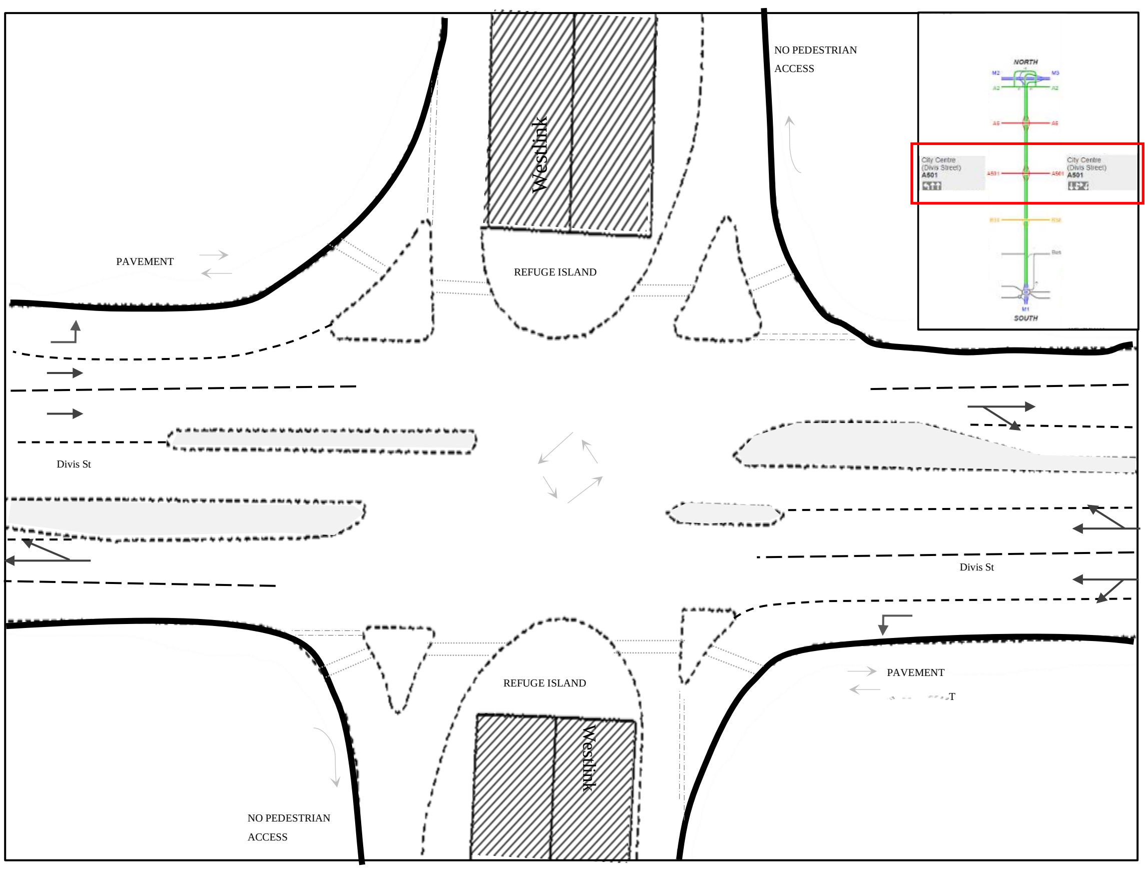

Figure 10 *Site plan sketch*

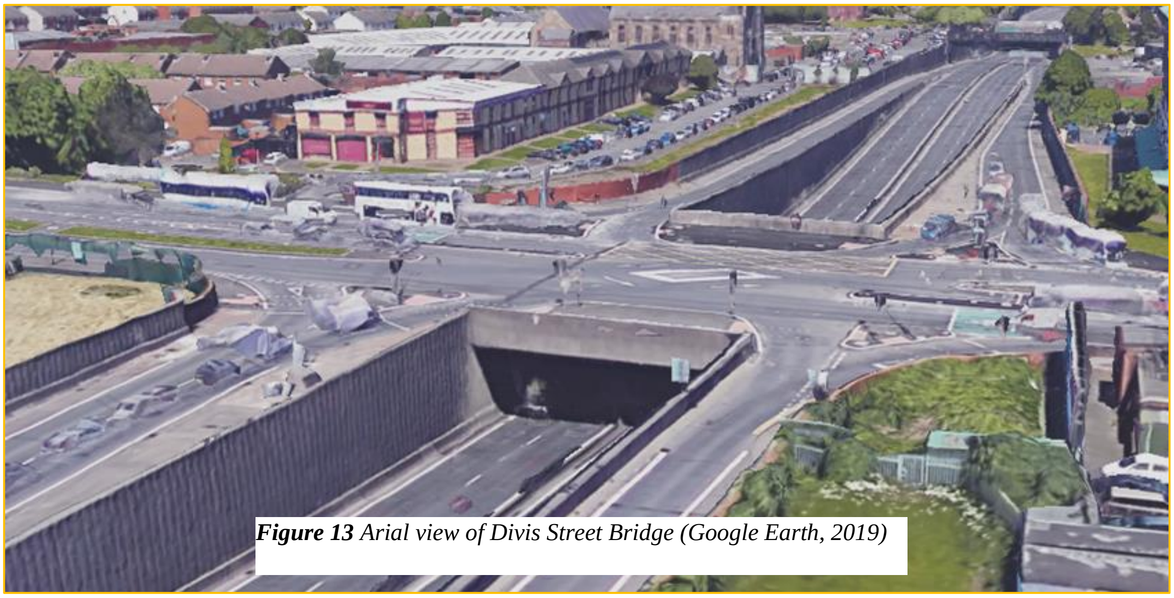

Figure 13 *Arial view of Divis Street Bridge (Google Earth, 2019)*

Figure 12 *Divis Street Bridge from A12 Westlink northbound (Google Earth, 2019)*

20.05m

Combined concrete and metal restraint system, 1.44 metres in height.

0.4m

1.04m

Figure 15a *Northbound parapet (Google Earth, 2019)*

The current restraint system does not provide the necessary level of containment to safeguard vulnerable individuals against the 8.4m drop onto the Westlink.

Existing Parapet Configuration

Weathered concrete eyesore

Painted metal railing embedded in concrete base

Figure 15b *Southbound parapet (Google Earth, 2019)*

Parapet arrangement extends to the sides with the metal railing cutting off approximately 4.5 meters in, whilst the concrete barrier forms part of the sloping abutment.

Statutory Approvals

Planning and designing the proposed works would follow current technical approval guidance of highway structures. As Northern Ireland's Buildings Database does not identify the bridge as a listed site or of any other special designation, the normal planning route is deemed adequate. Below is a list of planning resources that would be consulted to keep the design proposals within the compliance boundaries:

i. The Roads (Northern Ireland) Order 1993 No. 3160 Part VII: Structures, works, etc. on, in, under, over or near a road.
ii. Manual of Contract Documents for Highway Works. Volume 1 - Specification for Highway Works. Series 400 Road Restraint Systems (Vehicle and Pedestrian).
iii. BS 7818:1995 Specification for pedestrian restraint systems in metal.
iv. Technical Approval Schedule (TAS). Schedule of Documents Relating to Design of Highway Bridges and Structures.
v. Application for consent to fix or place rails, beams, cables, arches etc. over a road (Department for Infrastructure).
vi. National Highway Sector Schemes 5B and 10B.
vii. Planning Portal UK
viii. The Construction (Design and Management) Regulations 2015

The Department for Infrastructure has the authority to grant consent for works that involve the placement or alteration of a structure along or across any road in Northern Ireland (The Roads (Northern Ireland) Order 1993). Therefore, final design proposals would be presented to the DfI to validate the fitness for purpose and safety of the project. Notifications to other statutory authorities such as Belfast City Council, would also be necessary to avoid delays and objections.

In compliance with the CDM Regulations (2015), design would take full consideration of site-specific hazards to ensure reasonably practicable solutions, thereby minimise construction risks. Site assessment has identified the following hazards:

Technical Constraints

The erection of new barriers along Divis Street Bridge would result in some alterations to the bridge's structure. As a result, in order to maintain the bridge's structural integrity, structural analysis has to be carried out to determine: (1) the method of assembly of the proposed barrier to the bridge, and (2) the effect of additional loading on the bridge's deflection limits and aerodynamic behaviour. It is a requirement of the DfI that such work is certified by a Chartered Engineer and conducted in accordance with the *National Highway Sector Schemes 5B* and *10B.*

Preliminary assessments indicate that Divis Street Bridge's SPUI structure, spanning 55 metres and supported by concrete abutments, is robust enough to sustain the additional superimposed dead load of a bigger barrier. However, a lightweight restraint system would be ideal to ensure deflections on the external girder are minimal.

In terms of aerodynamic effects, evidence [Fujino and Yoshida (2002), Smith et al. (2002)] suggest that wind-induced vibrations and other notable wind effects are generally confined to long, mostly suspension, bridges. Therefore, the installation of a new barrier would not increase Divis Street Bridge's susceptibility to aerodynamic effects.

The proposed barrier itself would be fabricated to withstand the effects of wind in accordance with *BS 7818:1995* and/or *DMRB Volume 1 Section 3 Part 3 – (BD 49/01) Design Rules for Aerodynamic Effects on Bridges.*

Other Factors

Programme

As stated in the earlier chapters, the site of the proposed project hosts one of the busiest interchanges in Belfast. Therefore, any works in the vicinity of the junction must have minimal impact on the network's traffic flow. To achieve this, use of precast units would be preferred to accelerate barrier installation and avoid a lengthy programme.

Funding

The erection of suicide barriers to prevent access to means at sites such as Divis Street Bridge is very uncommon in Northern Ireland and as mentioned earlier, literature review found no records of the DfI carrying out such work. Calls for physical suicide barriers rarely take off from the conceptual stages due to the presumed lack of significance or reluctance by the relevant departments to fund the works. Indeed, it is not practicable to put up a suicide barrier on each and every bridge in the region but the nature of the problem at Divis Street Bridge, as described in *Chapter 1*, warrants the installation of an effective suicide deterrent system at the site.

Barrier designs that are economically sound are more likely to be incorporated into the 'Westlink approach' suicide prevention strategy. Although no financial estimations will be made during this project, all project alternatives will be relatively inexpensive to implement.

Design Criteria

Design will be in accordance with BS7818 and other relevant standards as stated above. Additionally, to fulfil the key project objectives, specific design criteria were specified based on the feasibility report. These design criteria would formulate a screening matrix that would ultimately determine the optimal design choice.

i. **Functionality**
   - Barrier must be effective in deterring individuals from climbing or successfully jumping off Divis Street Bridge.

ii. **Structural Integrity**
   - Barrier must maintain the structural integrity of the bridge's superstructure as discussed in the *Technical Constraints* section.
   - Lightweight materials preferred.to minimise deflection and aerodynamic effects.

iii. **Cost**
   - Barrier must be cost effective to install and maintain.

- Adoption on other Westlink overbridges would be more attainable as part of the 'Westlink approach' strategy.

iv. **Aesthetics**

- Barrier must be aesthetically pleasing without obstructing views.
- An unimposing design that minimises the sense of enclosure that is usually associated with suicide barriers.

v. **Buildability**

- Barrier system must be easy to install and flexible with respect to application on the Westlink.
- Reasonably practicable installation with great consideration to the risk of working at height.
- Construction utilising fabricated units to reduce plant and personnel on site, thereby keeping disruptions and/or traffic diversions to minimal.

vi. **Durability**

- Barrier must satisfy current durability requirements, i.e. a minimum design life of 30 years for combined metal and concrete pedestrian parapets - *MCHW Vol. 1 Series 400*.

vii. **Innovation**

- Final design solution must be creative and innovative in line with ICE's attributes to help drive the civil engineering industry forward.

5. PROJECT ALTERNATIVES

Overview

This chapter presents the project alternatives to determine an optimal suicide deterrent system for Divis Street Bridge that will be developed further in the project. The need for the project was first raised by the *Square Cut Punt Crew* and *PPR*, arising from the fact that the existing parapet system failed, repeatedly, to deter distressed individuals from climbing over and taking the jump. Conceptual design work was carried out in *Autodesk Revit 2019*, leading to the following three original concepts:

- Combined Steel Railing & Billboard Structural Frame – Replacing the existing top railing with flat infill bar railings and a billboard frame.
- Curved Glass Screen – Replacing the existing top railing with a curved acrylic glass screen.
- Webnet System – Addition of a horizontal net below deck, extending at least 5 metres out from the edges of the bridge.

The three ideas, as well as a no-build scenario, are discussed in the next pages and were screened against the design criteria established at the end of the *Feasibility Study* chapter. All the conceptual designs generally meet the design criteria, but screening was necessary to systematically determine the optimal alternative. The process of scoring the alternatives was conducted based on research, engineering judgement and a public survey.

The final proposal, presented in the last chapter, would incorporate additional ‘soft’ measures; details of which have not been discussed in this chapter. In the UK, barriers would usually be accompanied with helpline signage, i.e. Samaritans or NHS Direct contact details, CCTV and in some cases trained staff to patrol the site (Public Health England, 2015).

Alternative 1

Combined Steel Railing & Billboard Structural Frame

Concept

The first alternative comprises of flat infill steel bars and a billboard structural frame that would replace the existing metal railings, covering the full length of Divis Street Bridge on both sides. The steel bars approximately 1.0m in height would provide the necessary containment and spaced adequately in order to make them difficult to climb. Unlike conventional suicide barriers, a 2.5m high billboard frame has been incorporated into the design to provide additional height in an unimposing manner. The proposal would result in a new total height 4.54 metres for the bridge's restraint system, considerably higher than the existing parapet and in line with research (Hemmer, Meier and Reisch, 2017) that barriers least 2.3 metres in height would be adequate to secure a suicide hotspot.

Figure 16 *Alternative 1 Concept Rendering*

Alternative 2

Curved Glass Screen

Concept

Alternative 2 proposes the replacement of the existing metal railing with a curved glass screen made of acrylic panels fixed between evenly spaced steel columns.

The proposed installation would heighten the parapet to 2.54 metres, and its ‘inward curve’ design feature, which draws inspiration from the Grafton Bridge in New Zealand and Luxembourg’s Grand Duchess Charlotte Bridge, would hamper any suicide attempts at the site by making it difficult to climb on. Acrylic is the preferred material for construction because it is flexible, lightweight and transparent, thereby minimising the visual impact of the barrier within the area. In addition, the new ‘anti-climb’ glass barrier, due to its ‘canopy’ form, would provide some cover for pedestrians from the weather.

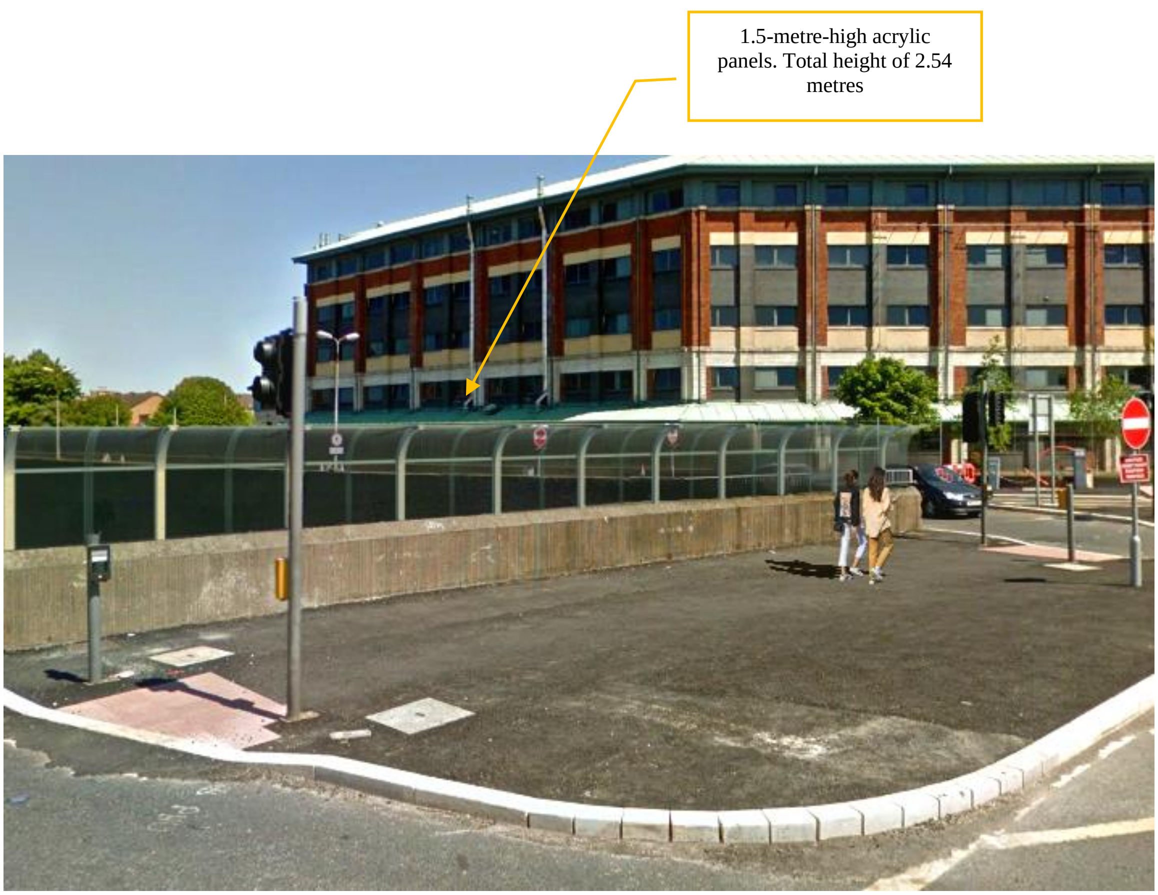

Figure 17 *Alternative 2 Concept Rendering*

Alternative 3

The ‘no-build’ approach

Under the no-build scenario, there would be no hard intervention at the site, meaning a continuation of current non-physical prevention measures.

At 1.44 metres high, the existing restraint system has failed to prevent any suicide attempts by jumping from Divis Street Bridge. The current strategy to deter suicide activity along the Westlink, as outlined in FOI documents retrieved by PPR, aims for a collaborative effort between Northern Ireland’s public service bodies (PHA, PSNI, NIAS, etc) to ensure emergency personnel effectively respond to any suspected suicide activity. However, a review of industry practice showed no examples whereby suicide attempts at bridges were successfully impeded by solely adopting soft prevention measures.

Figure 18 *Divis Street Bridge existing restraint system (Google Earth, 2019)*

Alternative 4

Webnet System

Concept

The final alternative proposes the addition of a horizontal netting system below the deck, extending at least 5 meters out from the edges of the bridge.

Sections of stainless-steel mesh would be stretched between horizontal support beams secured underneath the bridge. A series of cables would also form part of the support system attached to the bridge's superstructure, ensuring the nets are kept taut. Individuals who take the plunge from Divis Street Bridge would fall into the nets which gives enough time for rescue services to attend the scene. A detection system of motion sensors and pan-tilt-zoom cameras would also be installed to help identify any suspicious activity.

Adding nets is a flexible alternative which can be part of the 'Westlink approach' in tackling suicides without the obstruction of surrounding views.

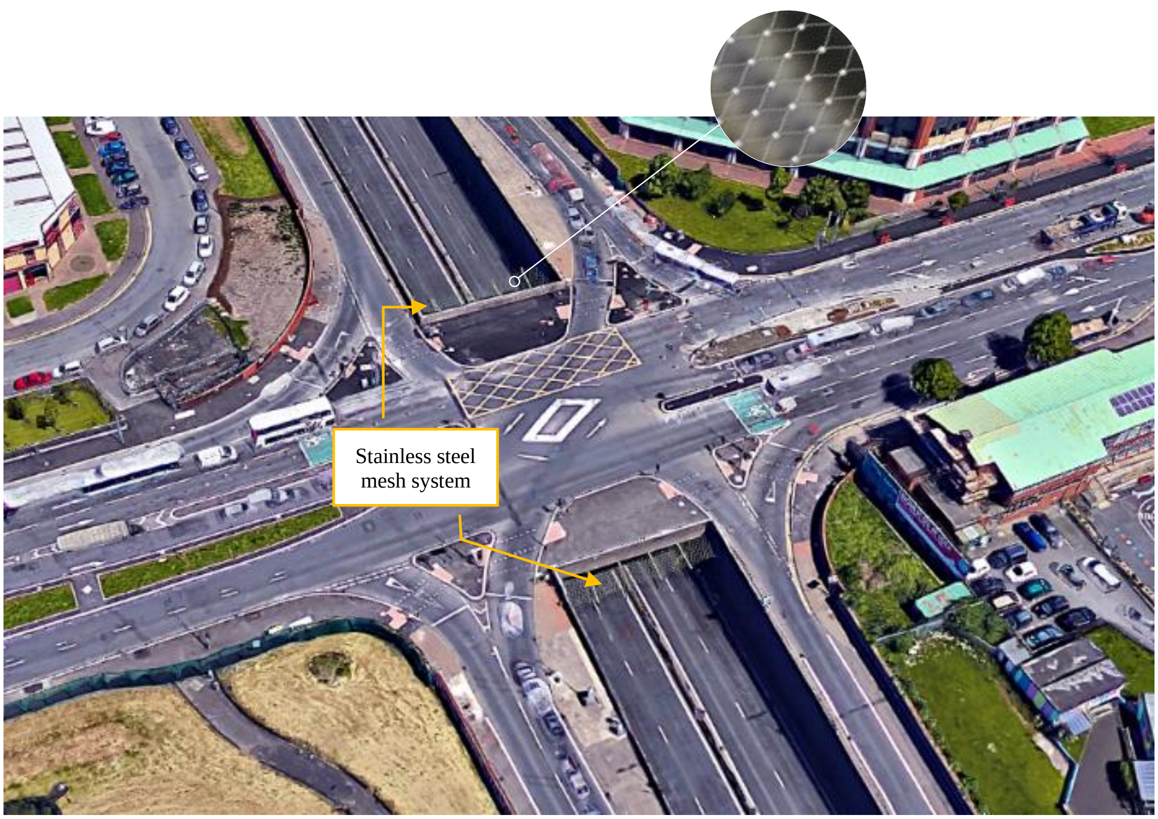

Figure 19 *Alternative 4 Concept Rendering*

Analysis of Design Solutions

Table 2 below shows the project alternatives evaluation matrix that was utilised to compare the four alternatives and determine the optimal barrier choice. As mentioned earlier, the evaluation matrix was derived from the design criteria established at the end of the *Feasibility Study* to develop technically feasible alternatives. Scoring the project alternatives was based on the Pugh method of decision analysis. Scores for *iv) Aesthetics* and *vii) Innovation* were determined through a public survey seeking the views of local residents on the proposals. Results of the 'Google Forms' survey have been included in Appendix A. In summary, 18 responses were received and 16 were considered acceptable to calculate the modal score for each alternative against the design criteria.

Table 1 *Scoring System*

+	Alternative meets design criteria
0	No effect on the evaluation criteria
−	Alternative does not meet design criterion

As a result, the Curved Glass Screen alternative scored the highest with a net score of 12; 3 more than the second best, Combined Steel Railing & Billboard Structural Frame, option. The alternative would be developed further to greater detail in the next chapter.

Table 2 *Screening of Project Alternatives*

Project Alternative (Net Score)	**Effective in deterring individuals from jumping off Divis Street Bridge.**	**Maintain the structural integrity of the bridge's superstructure.**	**Cost effective to install and maintain.**	**Aesthetically pleasing without obstructing views.** (Survey)	**Easy to install and flexible with respect to application on the Westlink**	**Durability – minimum design life of 30 years, in accordance with current standards.**	**Creative and innovative solution.** (Survey)
Combined Steel Railing & Billboard Structural Frame (9)	Steel slat alignment makes it difficult to grip and the billboard element would be impossible to climb over. + + +	Significant loading will be applied to the concrete base. –	Use of common and readily available materials. The galvanised steel would require minimal maintenance. Billboard element could generate considerable income. +	+	Removal of the existing metal railing, either by cutting or pulling out the embedded posts, would be the biggest challenge. Otherwise installation follows conventional construction procedures. +	Longevity with Zinc coating of up to 60 years. + + +	+
Curved Glass Screen (12)	Inward inclination of the barrier means it is physically impossible to get to the top for a jump. + + +	Acrylic is lightweight, having a density 7 times less than that of steel. + +	Synthetically manufactured, therefore quality determines cost. Routine maintenance necessary to maintain appearance. – –	+ + +	Removal of the existing metal railing, either by cutting or pulling out the embedded posts, would be the biggest challenge. Panels can be easily fabricated. +	Service life of approximately 30 years with adequate maintenance. + +	+ + +
No-build (-7)	Failed to deter any suicide attempts. – – –	No effect on the bridge's stability. 0	No construction costs. + + +	– –	No new work is carried out. 0	Closer to the end of its serviceable life. – –	– – –
Webnet System (2)	Any jumpers would be caught in the nets and rescued. + +	Support system would be integrated in structure beneath the deck, meaning the entire superstructure can sustain the load. + + +	Although conventional materials would be utilised, securing the bridge with the standard of nets required would be more expensive than each of the other alternatives. Nets would require regular cleaning. – – –	0	Horizontal supports would have to be safely secured underneath the bridge, causing serious disruptions. – –	Stainless steel-made but greatly affected by weather and constant tension. +	+

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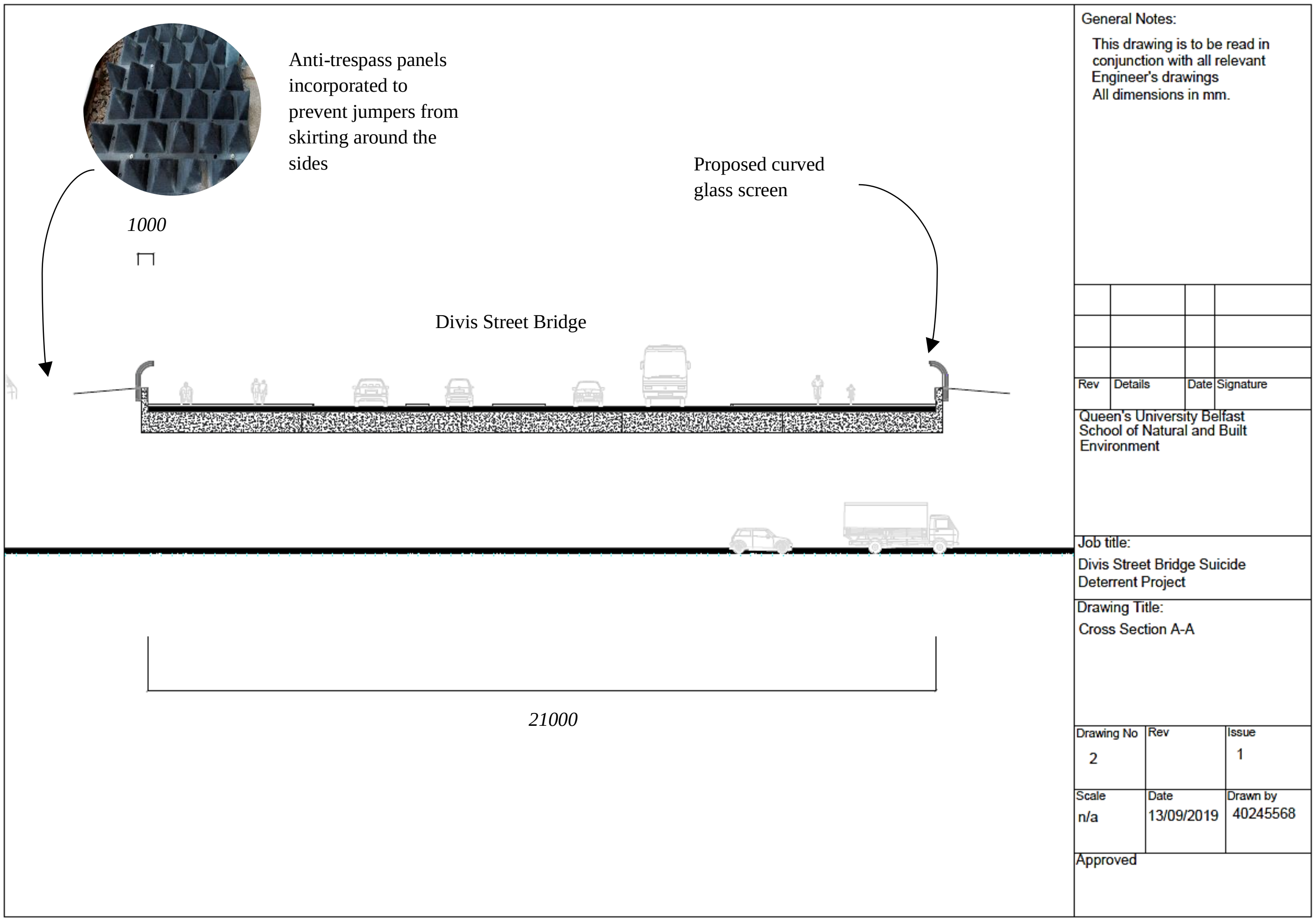
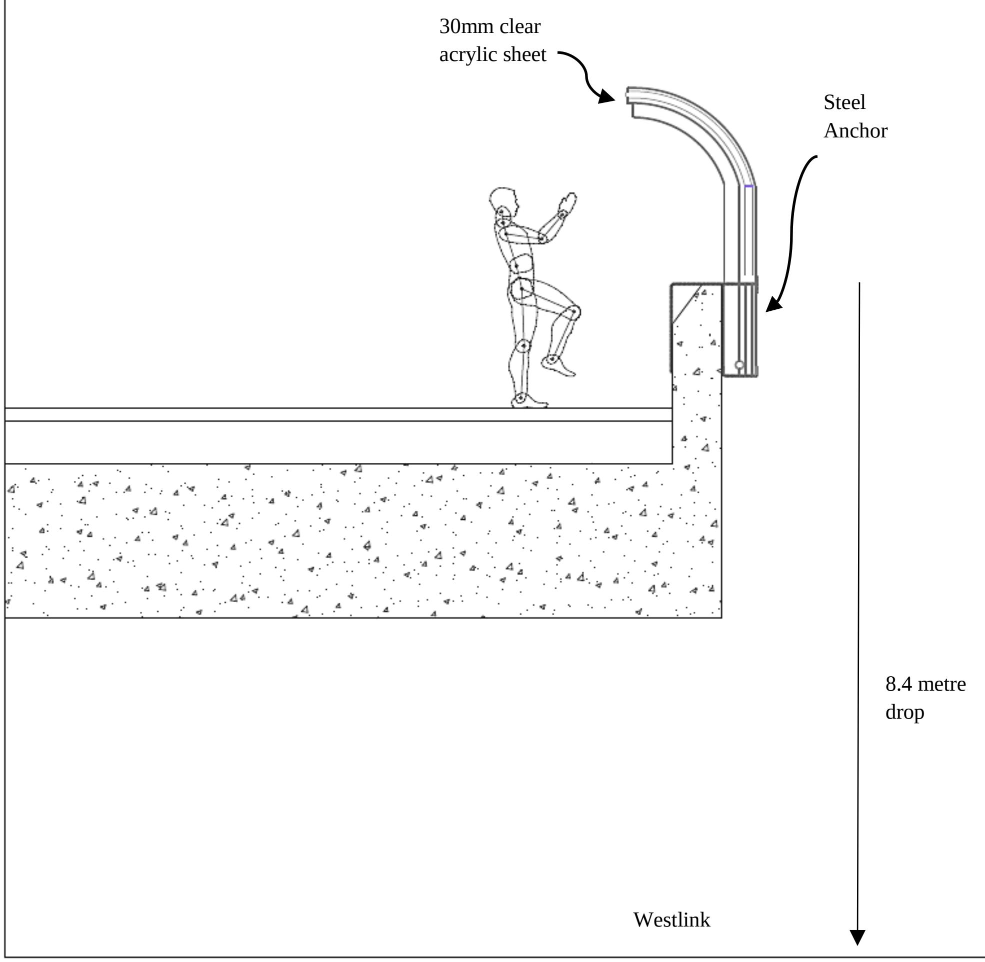
6. FINAL PROPOSAL





General Notes:

This drawing is to be read in conjunction with all relevant Engineer's drawings
All dimensions in mm.

Rev	Details	Date	Signature

Queen's University Belfast
School of Natural and Built Environment

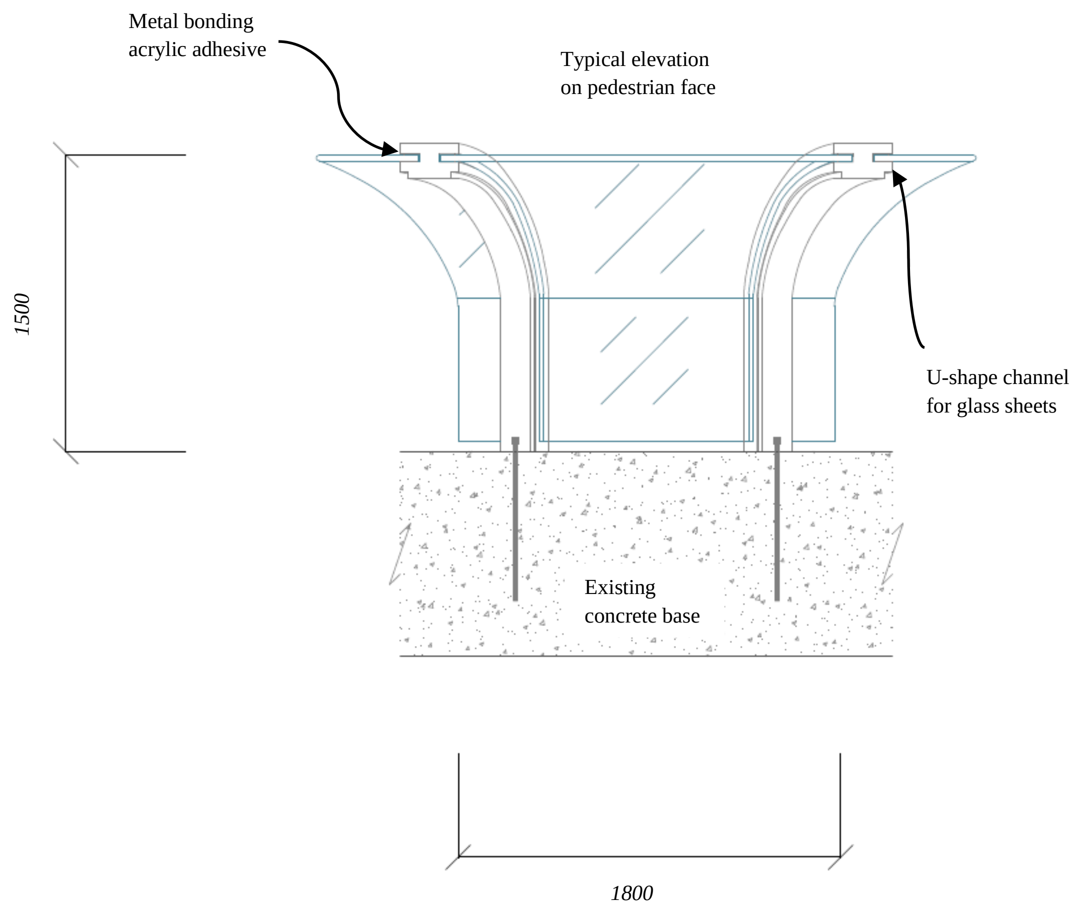
Job title:
Divis Street Bridge Suicide Deterrent Project

Drawing Title:
Section Through Barrier

Drawing No	Rev	Issue
3		1

Scale	Date	Drawn by
n/a	13/09/2019	40245568

Approved



General Notes:

This drawing is to be read in conjunction with all relevant Engineer's drawings
All dimensions in mm.

Rev	Details	Date	Signature

Queen's University Belfast
School of Natural and Built Environment

Job title:
Divis Street Bridge Suicide Deterrent Project

Drawing Title:
Typical Panel

Drawing No	Rev	Issue
4		1
Scale	**Date**	**Drawn by**
n/a	13/09/2019	40245568

Approved

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Appendix A: Goggle Forms Responses

Thesis Project Alternatives Feedback (Responses)

Timestamp	Alternative 1: Combined S	Alternative 1: Combined S	Alternative 2: Curved Gla	Alternative 2: Curved Gla	Alternative 3: No-build [iv]	Alternative 3: No-build [vii	Alternative 4: Webnet Sys	Alternative 4: Webnet Sys	Do you have any further comments to make on the proposals?
04/09/2019 23:35:09	+1	+1	+3	+3	-1	-3	+3	+1	
05/09/2019 00:47:27	+1	+2	+3	+3	-2	-3	0	+2	
05/09/2019 00:53:32	+2	+2	+3	+3	-2	-3	0	+2	
05/09/2019 01:32:59	-3	-1	-1	0	-2	-3	0	+1	
05/09/2019 02:02:41	+1	+1	+1	+1	+2	+2	+1	+1	
05/09/2019 02:07:43	0	0	0	0	0	0	0	0	
05/09/2019 03:11:58	+1	0	-2	0	+1	-1	+1	+2	
05/09/2019 07:44:20	+2	+2	+3	+3	-2	-3	+2	+2	
05/09/2019 08:44:36	+1	+1	+3	+2	-3	-3	+3	+3	
05/09/2019 08:59:37	+1	+3	+3	+3	-3	-3	+3	+3	
05/09/2019 09:26:53	+1	+2	+2	+2	-1	-3	0	+1	
05/09/2019 09:31:09	+1	0	+2	+1	0	0	+2	+1	
05/09/2019 09:41:17	0	0	+2	+1	0	-3	+1	+2	
05/09/2019 10:28:35	+1	+1	+2	+2	-3	-3	+2	+2	
05/09/2019 11:46:59	-1	-1	+3	+2	-2	0	-1	+1	
05/09/2019 13:11:40	+2	+3	+2	+1	0	0	+1	+1	
05/09/2019 13:54:23	-1	-2	-2	-1	-3	-3	-2	-2	
05/09/2019 17:00:06	-2	-3	-2	-2	-2	-3	-3	-2	