Star Path: Photo Luminescent Road Markings: Trial Study

Final Report

SEStran / Scottish Road Research Board

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Table of contents

Chapter		Pages
1.	**Introduction**	**1**
1.1.	Background to Study	1
1.2.	Aim, Objectives and Methodology	1
2.	**Desktop Study**	**3**
2.1.	Introduction to Desktop Study	3
2.2.	Glowing Road Report	3
2.3.	X-Route	3
2.4.	Summary	4
3.	**Case Studies**	**5**
3.1.	Smart Highways, The Netherlands, 2014	5
3.2.	Lidzbark Warminski Path, Poland, 2016	5
3.3.	StarPath, 2014-2017	5
3.4.	Summary	6
4.	**Material Investigation and Selection**	**7**
4.1.	Stakeholder Expectations	7
4.2.	Available Products	7
4.3.	Material Selection	9
5.	**Field Trial**	**11**
5.1.	Site Selection	11
5.2.	Installation	14
5.3.	Monitoring	16
6.	**Conclusion and Recommendations**	**17**
6.1.	Progress	17
6.2.	Effectiveness	17
6.3.	Recommendations and next steps	20
Appendices		**20**
Appendix A.	**Findings and Recommendations 'Glowing Roads' Report**	**21**
A.1.	Findings	21
A.2.	Limitations	21
A.3.	Other Developments	22
A.4.	Summary	22
A.5.	Considerations	23
A.6.	Next Steps	23
Appendix B.	**X-Routes Report – Findings and Actions**	**24**
B.1.	Information & Knowledge	24
B.2.	Social Barriers	24
B.3.	Common Barriers	24
B.4.	Quality of Routes	24
B.5.	Conclusion	25
Appendix C.	**The Vennie Feedback on Materials (Example)**	**26**
Appendix D.	**The Vennie Feedback on Trial Site (Example)**	**27**

Tables

Table 4-1 Stakeholder Expectations 7
Table 4-2 Material Comparison 7

1. Introduction

1.1. Background to Study

The Scottish Road Research Board (SRRB) funded and published a report by CH2MHILL in 2014 entitled 'Investigating the Potential for Reactive 'Glowing' roads as an Initiative on the Scottish Road Network'[1]. The report concluded that the innovation was not well developed at that time, but that there is potential for future development. The report recommended that a product 'StarPath' developed by PRO-TEQ was worthy of further consideration.

In November 2016, Young Scot published a SEStran funded report titled 'X-Route – Co-Designing Active Travel'[2]. This involved groups of young people, from various socio-economic backgrounds across the southeast of Scotland, discussing the barriers they face when considering using active travel as a means of transport. The report was conducted using Young Scot's Co-design method in which young people are involved considerably earlier in the decision-making process through a highly participative approach developing informed insights, ideas, recommendations and solutions for service development, policy and practice.

Participants developed a series of ideas and recommendations to improve cross boundary active travel in and around their local areas, with the intention of these routes becoming a viable option and an integral part of travel for young people and their wider community. This research will expand on the X-Route study which puts young people at the heart of collaboratively developing regional cycling infrastructure, by producing tangible outcomes. One suggestion at the explorative workshops was for glow-in-the-dark paint on active travel routes, thus tying in X-Route with the 2014 'Glowing Roads' report that was conducted by CH2M HILL into the use of glow in the dark road markings.

1.2. Aim, Objectives and Methodology

1.2.1. Aim

The aim of this study is to follow on from suggestions given in the 'X-Route' report and the CH2MHILL 'Glowing Roads' study, to research, trial and evaluate the viability of a glow in the dark strategy as an improvement to active travel routes in Scotland.

1.2.2. Objectives

The objectives undertaken to achieve this were:

- Understand the outcomes from previous reports undertaken relating to 'glowing' paths/markings and active travel and assemble case studies of current examples,
- Consult with local youth groups and West Lothian Council to determine aspirations and ideas for the project and criteria against which the possible solutions were assessed,
- Investigate, evaluate and select suitable, currently available products to trial,
- Assess and select trial site(s),
- Undertake a trial of the chosen products,
- Evaluate trial in terms of its effectiveness as a light source, perception of increased safety, required maintenance etc. and
- Provide final recommendations regarding the product and possible future use.

1.2.3. Methodology

The following tasks were undertaken to achieve the project objectives:

[1] 'Investigating the potential for reactive 'glowing' roads as an initiative on the Scottish road network', SRRB, March 2014
[2] 'X-Route Co-Designing Active Travel' SEStran and Young Scot, 2016

- A summary was written to show understanding of the outcomes from previous reports and research was undertaken to identify case studies of glow in the dark paths or road markings,
- Face to face meetings were undertaken with the local council and a local youth group to understand the issues they regard as integral to the project,
- Available products were investigated and a shortlist was presented to the identified stakeholders. Suitability of the materials and feedback from these presentations informed material selection for the trial,
- A discussion and feedback session was held with the Vennie Youth Group to identify trial sites,
- A trial was undertaken and monitored regularly via site visits supplemented by the participation of a local youth group,
- The trial was assessed by meeting with, and gathering feedback from, the youth group and social media platforms. Cycle and pedestrian counters were considered to validate if the installation increased path usage and therefore encouraged active travel. However, the high cost of the equipment coupled with the relatively low usage of the path led this strategy to be discounted and the qualitative approach on effectiveness to be used.

2. Desktop Study

2.1. Introduction to Desktop Study

The primary aim of the desktop study was to review the previous research on glow in the dark road markings conducted by CH2MHILL and to understand why glow in the dark paths were identified as a way to encourage active travel in the X-Route report. The following sections summarise the findings of the desktop study and identifies areas such as products available in 2014 and the factors that will influence additional active travel as a foundation for this research and trial.

2.2. Glowing Road Report

In 2014, CH2MHILL was commissioned by the Scottish Road Research Board (SRRB) to investigate the potential for 'glowing' road markings after the publicity of the Van Gogh Cycle Path (Netherlands) by Dutch Artist Dann Roosegaarde. The aim was to thoroughly explore the material and its possibility for use within Scotland. At the time, the Van Gogh path and 500m of road markings developed by the same company were still in testing phase. However, the report concluded that using the material in Scotland would only provide 'an hour or so' of illumination after sun set and that length of discharge would have to be more fully proven to validate the claims of up to ten hours as stated by the company.

The report also referenced a product called 'StarPath' being trialled in a park in Cambridge which showed promising results on footways and cycle paths but would have to be further developed for use on roadways due to strict British and European Standards. The report determined that although no materials were currently available at that time the potential for successful development of a glowing road marking was high. A summary of the main points of the report can be found in Appendix A.

2.3. X-Route

The Young Scot X-Route report published in 2016 focuses on determining the obstacles which deter young people from choosing to use active travel. The process involved youth groups from various socio-economic backgrounds voicing the widespread issues affecting active travel participation and then generating ideas and recommendations on how these could be tackled. The main outcomes from the report can be found in Appendix B.

The issues identified were extensive but can largely be categorised into 4 themes:

2.3.1. Ability:

Lack of experience in cycling coupled with the high initial cost of equipment stop aspiring cyclists at the first hurdle. For those who can cycle and who own equipment; lack of facilities such as storage, washing services and interfaces with public transport at destinations discourage them from utilising cycling as a transport mode.

2.3.2. Quality:

The quality of some cycle paths makes cycling unattractive due to irregular surfaces, poor maintenance, overgrowth, narrow bottlenecks, lack of lighting and lack of signage.

2.3.3. Safety:

Linked to the quality of the paths; cycling in the dark, getting lost and being injured were all seen as likely possibilities of cycling through some current path networks and therefore seen as unsafe by young people and their families.

2.3.4. Attitude:

Overall, cycling is a hobby undertaken by certain groups (BMXers, mountain bikers) rather than as a transport mode. The opinions of peer groups and friends were listed as having a high influence on whether an individual would cycle regularly as well as the perceived attitude of road users towards cyclists.

2.3.5. Outcomes

After identifying these issues, participants were asked to think of solutions to improve active travel. The ideas were varied and innovative, including ideas such as cycling advocates in schools, bike storage facilities, park and ride for cyclists at local transport links and new routes to places currently cut off from the cycle network (Stirling, Glentress Mountain Bike track). Ultimately 'Glow in the dark' cycle paths were highlighted as an option which tackled many of the issues raised above. From this report, SEStran obtained funding from the SRRB to commission this research and explore the idea further.

2.4. Summary

The previous research undertaken has suggested that the provision of glow in the dark cycle paths would encourage active travel among young people by improving the feeling of safety and the quality of the cycle route network. In 2014 CH2M identified that there were products available which may be able to provide glow in the dark features as road markings in the near future and identified a product which, although would not meet British Standards for road markings, may be functional on a cycle path network. The next step is to determine if these products have been developed further since 2014 and if any case studies of glow in the dark paths can be found.

3. Case Studies

3.1. Smart Highways, The Netherlands, 2014

Smart Highway is a series by artist Daan Roosegaarde in collaboration with Heijmans. The movement has two notable examples.

3.1.1. Glowing Lines, Oss

'Glowing Lines' was highlighted in the CH2M report but at that time was still in laboratory testing. The material has been piloted on 500m of highway outside of Amsterdam. The road markings are applied as a photo luminescent paint which charge during the day from exposure to sunlight and emit light in darkness. No official report on effectiveness could be found. However, a press release from the company stated the material deteriorated due to wet weather conditions and the product is now in further phases of laboratory testing.

3.1.2. Van Gogh – Roosegaarde Cycle Path, Eindhoven

This 600m long path was also identified in the CH2M study and is constructed from blue/green aggregate coated in a Photo-luminescent substance (Used in glowing lines project) laid on top of wet concrete and then buffed to provide a smooth cycle surface. The aggregate charges on exposure to the sun and emits light during dark periods for up to 8 hours. The system is supplemented using solar powered LEDs on the edge of carriageways and at sharp deviations in route. This ensures efficiency if the weather is not bright enough to recharge the path. No recent reviews of the design life or effectiveness of the pathway are available. However, the pathway is still advertised on Holland's Tourist Information and Van Gogh Enthusiast websites so it can be presumed that it is still operational.

3.2. Lidzbark Warminski Path, Poland, 2016

The Lidzbark Warminski path was inspired by the Van Gogh Roosegaarde path and is based on similar properties. The 100m x 2m track was designed by a materials technology competence centre for asphalt, concrete, earthworks, and geotechnical engineering called TPA Institute Badan Technicznych. In this example phosphors are mixed with aggregate and charge via sunlight to emit light for over 10 hours. Unlike the Van Gogh path, this example does not use any additional LEDs and is therefore self-sufficient. Having only been unveiled in October 2016 there are no studies on the long-term effectiveness of the material and it is not a product which is currently available for purchase.

3.3. StarPath, 2014-2017

The StarPath product was highlighted as a possible future material in the CH2MHILL Glowing Lines report as it did not demonstrate adherence to British road standards and therefore not a viable option for road markings at the time. The product was installed in Christ's Pieces Park, Cambridge in 2013 on a 150m length of path and is a mixture of photo luminescent powder and aggregate which is sprayed onto an existing path and finished with a polyaspartic sealant. The material absorbs UV light rather than direct sunlight and therefore claims a minimum of 16 hours' discharge. Similar to the case studies above, there are numerous press articles on the installation of the path but no official studies on its effectiveness or design life. The company is currently working on several other path installations, the most recent being installed in 2017 in Shanghai, but also have installations in Singapore and New Zealand. StarPath is provided by UK based company PRO-TEQ and is available to purchase.

3.4. Summary

Although it has been four years since the ‘Glowing Roads’ report was published, examples of glowing road markings or paths are still uncommon and there has never been an example tested in Scotland. Three out of the four examples found were identified in 2014 with one new installation identified in Poland. However, the Star Path brand has seen a large expansion with various applications of the product. None of the case studies provide reports or reviews of the effectiveness of the materials (Glowing Lines deteriorated but was back in lab testing for development) and one is supplemented with additional LED lighting. Review of the case studies found would suggest that not much notable progress has been made since the 2014 report. The next step in this research is to determine what glow in the dark products are available to purchase- if any- in addition to the StarPath product and to determine the suitability of the materials for this trial study.

4. Material Investigation and Selection

4.1. Stakeholder Expectations

Initial meetings were undertaken with relevant stakeholders to determine expectations from the trial and to identify vital criteria for any trial material(s).

The Vennie Youth Group in Livingston was one of the original groups involved in the X-Route report. As such, it was decided the trial site would be located somewhere in the proximity of the youth club, highlighting the tangible outcomes from Young Scots co-design technique. The meeting and collaboration with the group members highlighted aspirations for the trial, such as an innovative/cool installation, a solution that would make cycling feel safer in the dark and that wouldn't damage the environment. Generally something that would motivate members of the local community to cycle more or utilise a path that wasn't currently used.

Permission to trial glow in the dark materials on paths surrounding the Vennie was sought from West Lothian Council (WLC) who own and operate the path network in the area. WLC were happy to be involved in the project assuming that the path would not be negatively affected long term; any products installed could not require extensive additional maintenance and the safety of the path users would not be compromised.

SEStran highlighted the need for new innovative products or technologies that would be effective in encouraging young people to use pathways for active travel. Young people were to be included in the development of the trial proposals and their input into the process was considered to be essential to obtaining a successful outcome. Table 4-1 summarises the stakeholder criteria for the trial.

Table 4-1 Stakeholder Expectations

Stakeholder	The Vennie Youth Group	West Lothian Council	SEStran
Expectations	Innovative	Low maintenance	Innovative
	Improved safety	Safe	Effective
	Cool / fun	No negative impact on path use	Low cost

4.2. Available Products

4.2.1. StarPath

StarPath discussed above as a case study, is a material previously mentioned in the CH2M Study developed by a UK based company PRO-TEQ. The photo-luminescent material absorbs UV light and claims a minimum of 16 hours discharge. The material can be quickly applied on top of existing pathways (concrete or tarmac) if in 'reasonable' condition. PRO-TEQ are the sole suppliers and traders of their product and as a company has seen a rise in publicity with ever increasing applications for their product from spraying cars to clothes.

Regarding suitability to this project StarPath may be a feasible option. It is an attractive feature and the use of UV light rather than sunlight is more suitable to the overcast Scottish climate. The application on top of existing pathways requires a bound surface and therefore this may not be suitable for many paths in Scotland and the relatively new technology makes it quite high risk in terms of its effectiveness and performance over time. An area of 1.2m^2 costs £74.40 plus installation, shipping and VAT. However, this could be reduced by spraying alternating sections or a singular edge strip but this may diminish appeal / effectiveness. Also, this treatment is 45% more expensive than constructing a new tarmac path [3].

[3] Estimating Price Guide for Path Projects, Paths for All Scotland, 2014

4.2.2. Eco-Disc

Eco-Discs are also supplied by PRO-TEQ. These are moulded polypropylene composite discs injected with the StarPath photo-luminescent Powder and therefore work in the same way, by absorbing UV energy to emit a glowing light. They are approximately 100mm in diameter and 15mm deep with a textured surface to negate slip hazards. The company claim the Eco-Disc can generate light for over 10 hours even with minimal exposure. The discs can be installed into or on road surfaces using silicone adhesive but may also be securely fastened or screwed to posts or bollards.

Regarding suitability to this project, Eco-Disc may be a reasonable selection. Similar to StarPath, the 'glow in the dark' feature is an attractive option and the ability to specify the number and layout of discs offers a way to minimise costs if required, accepting that this may reduce the overall effectiveness. The ability to install on bollards or posts ensures that they could be used on all pathways, bound or unbound, with bollards chosen in response to the character of individual sites. Maintenance may be an issue with carriageway installation as leaf fall and dirt may obscure light emission. Eco-Discs are priced at £3.95 per unit + installation/shipping and VAT plus the cost of bollards (if required).

4.2.3. Lumilight

Lumilights are very similar to Eco-Discs - a plastic mould filled with a photo-luminescent substance which absorbs UV rays when exposed to sunlight and then produces a glow when in darkness. The discs are approximately 120mm in diameter and 6mm deep with a smooth surface. The Lumilights are provided by TDC, a transport management company based in Livingston where the trial will take place. The manufacturer claims that Lumilights can emit light for up to 12 hours in dark periods and have a design life up to 5 years.

The suitability of this product is similar to that of Eco-Discs, being able to choose the number and layout of the discs could minimise costs but maintenance would be required in case of dirt or foliage obstructijng light emission. The Lumilights are more expensive than the Eco-Disc at £10 per disc + installation/shipping, VAT and cost of bollards (if required).

4.2.4. Solar Powered LED

There are a number of solar powered LED lights marketed for use on cycleways. They have been installed at a number of locations across the country and are available in various colour combinations. Some installations include SMART technology, for example coloured LEDs that shine blue when the temperature falls towards freezing point.

SolarEye is an example of a solar powered LED inserted into the ground to increase visibility on cycle paths during hours of darkness. The manufacturer claims that 8 hours exposure to daylight will provide 200 hours of light on a steady setting. The lights are visible from 500m and have a life span of 8 years. The LEDs are available in an array of colours and have steady or flashing settings. Installation is relatively easy using a milling tool to create an 80mm deep by 80mm wide recess for the unit which is bonded in place using a resin adhesive. The units can be installed in concrete, tarmac, block paving or wood and are low profile and skid resistant.

With regards to suitability of this product, SolarEye may be a viable choice. The ability to place the LEDs at any intervals/ alignment is an option to reduce costs and the short charging time compared to emitting time is a plus when considering Scotland's weather conditions. Solar power is a proven technology and therefore a suggested design life of 8 years is a reliable estimate. Maintenance may be an issue with this option as leaf fall and dirt may obscure light emission. Like StarPath, this option is not applicable to unbound surfaces and the LED is not as typically 'glow in the dark' as the other available options. Regarding cost, one SolarEye is £29.80+VAT per light which includes the required resin but not installation. As a reference, similar LEDs from a company were quoted as £50 per installed unit and LEDs including SMART technology up to £150.

4.2.5. Luminescent Paint

Our research did highlight one product of luminescent road marking paint which is available to buy. The paint is marketed as a road marking paint which resists weather conditions and is twice as adhesive as a traditional

product. The paint is applied over a white primer coat in the conventional road marking method. The paint is comparable to the glowing roads case study in The Netherlands but is also reflective so will emit more 'glow' when light is shone upon it. The product claims a glow time of 13 to 15 hours and a design life of 15 years. The supplier is from China and was not able to provide any current examples of the paints use or any health and safety data for the product. Communication with the supplier was sporadic and unreliable and the cost per unit was extremely high in addition to a long delivery time. Ultimately due to these issues it was decided to discount this material from the trial.

4.3. Material Selection

4.3.1. Comparison

Table 4-2 shows a comparison of each available product if installed on a 100m path. The Lumilights and Eco-Discs would be installed at 3metres from centre to centre staggered on either side of the pathway and the SolarEyes at 12metres centre to centre as these are likely to provide a far brighter 'glow'. The StarPath resin would be installed as a 150mm wide delineation strip on either side of the path, a cost for a full path installation is also shown.

The Eco-Disc and Lumilights are similar products however the Eco-Disc are less than half the price, a thicker more durable looking disc and provide a textured surface which may influence the amount of glow provided. The Lumilights are half the depth of the Eco-Discs and will therefore require less intrusion into the path surface.

The SolarEye is a well-known solar powered technology and therefore will reliably produce a bright light source. These LEDS are approximately three times the price of the Eco-Disc and a similar price to the Lumilight but could be placed further apart to reduce cost, with a compromise to overall effectiveness.

The StarPath resin is by far the most expensive at seven times the price of the Eco-Disc to supply delineation strips and 50 times the price to cover the entire pathway. The supplier only provides examples of fully installed paths and so delineation strips may be less effective.

Table 4-2 Material Comparison

	Eco-Disc	Lumilight	SolarEye	StarPath 30mm	Star Path 2m
Layout	Discs at 3m c/c = 66	Discs at 3m c/c = 66	Light at 12m c/c = 16	2 x strips at 150mm width = 30m^2	Path Width 2m= 200m^2
Cost per unit	£3.95 per disc	£10.00 per disc	£29.80 per disc	£74.40 per 1.2m^2	£74.40 per 1.2m^2
Cost per 100m	£260.70	£660.00	£476.80	£1, 860.00	£12,400.00

4.3.2. Stakeholder Feedback

The above products show the extent of current 'glow in the dark' materials which would be suitable to trial on paths in Livingston. These were presented to The Vennie youth group, West Lothian Council and SEStran.

A power point presentation was given to The Vennie youth group (approximately 20 members in attendance) to inform them of the possible trial options. A feedback discussion and written forms collected the comments and thoughts on the available products (Example forms Appendix C). StarPath received the greatest response and was seen as the most encouraging option to increase active travel. Participants stated they would still be encouraged to use a StarPath if the material was installed as shapes (arrows) or delineation strips instead of on the entire pathway. Eco-Disc, Lumilights and SolarEye also received optimistic reactions and the ability to

provide alternating colours was considered an advantage. The general feedback was that Lumilights and Eco-Discs met the criteria of ‘glow in the dark’ more so than the SolarEye which emits a more ‘conventional’ light. Generally, the ability to delineate the edge of the path with either the StarPath resin or with the Eco-Discs or Lumilights would make a path feel safer to use as there would be less chance of cycling off a kerb or edge.

West Lothian Council (WLC) understood that the StarPath spray looked very good but were concerned about the effect on path drainage as strip of the material laid along the edge of the path could create a water-ponding hazard and, if it were to be applied in strips (as the budget for this project would allow) they would be apprehensive about a possible trip hazard as the strips would be minimum 15mm higher than the path surface. The ability to mill the Eco-Disc, Lumilights and SolarEye into the pathway was therefore seen as a positive and the shallow depth of the Eco-Disc and Lumilights were considered advantageous as, if they were removed, the impact on the path would be minor when compared to the deeper installation required for the SolarEye. WLC agreed that maintenance would not be a major issue as Scotland’s wet weather would provide regular clearing of the products from dirt and debris.

The products were also presented to the Project Manager at SEStran for feedback and opinions. Similar to the findings above, StarPath, Eco Disc and Lumilight were identified as good options for the trial. The feedback suggested that the Eco-Disc appeared to be a more robust and substantial product than the Lumilight due to its thickness and textured surface. In addition, it was suggested that although the SolarEye is a suitable option for lighting cycle ways, the trial should focus on new and innovative materials as solar powered LEDs were already in use throughout West Lothian and Edinburgh.

4.3.3. Selection for Trial

After considering the feedback and comparisons above, the Eco-disc and Lumilight were selected for a trial study. Although these are similar, the difference in suppliers, manufacturing, size and texture may influence the effectiveness of the discs and therefore trialling both will allow this to be assessed.

The SolarEye was not selected, as solar powered lighting is already commonly used and there are examples within West Lothian which could be used for comparison against the selected products. Finally, the StarPath resin was also ruled out due to the concerns of the path owner on the effect of the resin on the path in terms of drainage and safety. The high cost ensured only delineation strips could be provided within this project and this would not be as effective as a fully covered path as promoted by the suppliers and therefore may have given an inaccurate representation of the product.

5. Field Trial

5.1. Site Selection

As discussed above, The Vennie Youth Group has been involved in the project since the X-Route report and it was agreed the trial would be undertaken close to the youth club grounds so that the members could see tangible results from their participation. We met with members of The Vennie and set the following criteria for a trial location:

- It should be unlit or badly lit
- It should have a bound surface
- It should be accessible for ease of installation
- It should provide a link to useful amenities (shop/ school/ station) and therefore be used more frequently after installation

After a brainstorming session and discussion in which participants highlighted possible routes (Example Appendix D) the two following locations were selected (Figure 5-1).

Figure 5-1 Trial Site Location Map

5.1.1. Trial Location One

The first trial path extends from Livingston North Railway Station northeast and provides an important link from the train station to local housing and shops (Figure 5-2). The path runs parallel to the railway tracks on the northern side and is confined by some trees and vegetation on the southern side but receives sunlight throughout the day. The path is a bound surface with flush kerbing onto grass and is the only unlit route in the area. The current use is low in the evening and at night as it is perceived as very unsafe to walk along. This location will allow us to compare how the Eco-Discs and Lumilights perform after being 'charged' in a sun exposed area. The railway path is 300m long and therefore 100 Eco-Discs and 100 Lumilights were trialled in this location at 3m centre to centre staggered on each side of the path. Layout of the discs are shown in Figure 5-4.

5.1.2. Trial Location Two

The second trial path joins the railway path to Knightsridge East, near the vehicular entrance to the Vennie grounds through a large wooded area (Figure 5-3). The path links local housing to the Vennie and is in proximity to shops and schools. The path is lit with lighting columns approximately 80metres apart however due to the surrounding trees and vegetation the pathway has numerous dark areas. There is no kerb between the bound surface and vegetation and therefore the edge of the pathway is hard to distinguish, especially in darkness. This location will allow us to assess if ambient light (not direct sunlight) is sufficient to charge the Eco-Discs and Lumilights and if there is a difference in effectiveness when compared to the samples which receive direct sunlight at Trial Location One. The forest path is 150m long and therefore 50 Eco-Discs and 50 Lumilights were trialled in this location at 3m centre to centre staggered on each side of the path. Layout of the discs are shown in Figure 5-5. Figure 5-6 and 5-7 show the Eco-Discs and Lumilights pre- Installation.

Figue 5-2 Trial Location One

Figure 5-3 Trial Location Two

Figure 5-4 Layout - Trial Location One

Figure 5-5 Layout - Trial Location Two

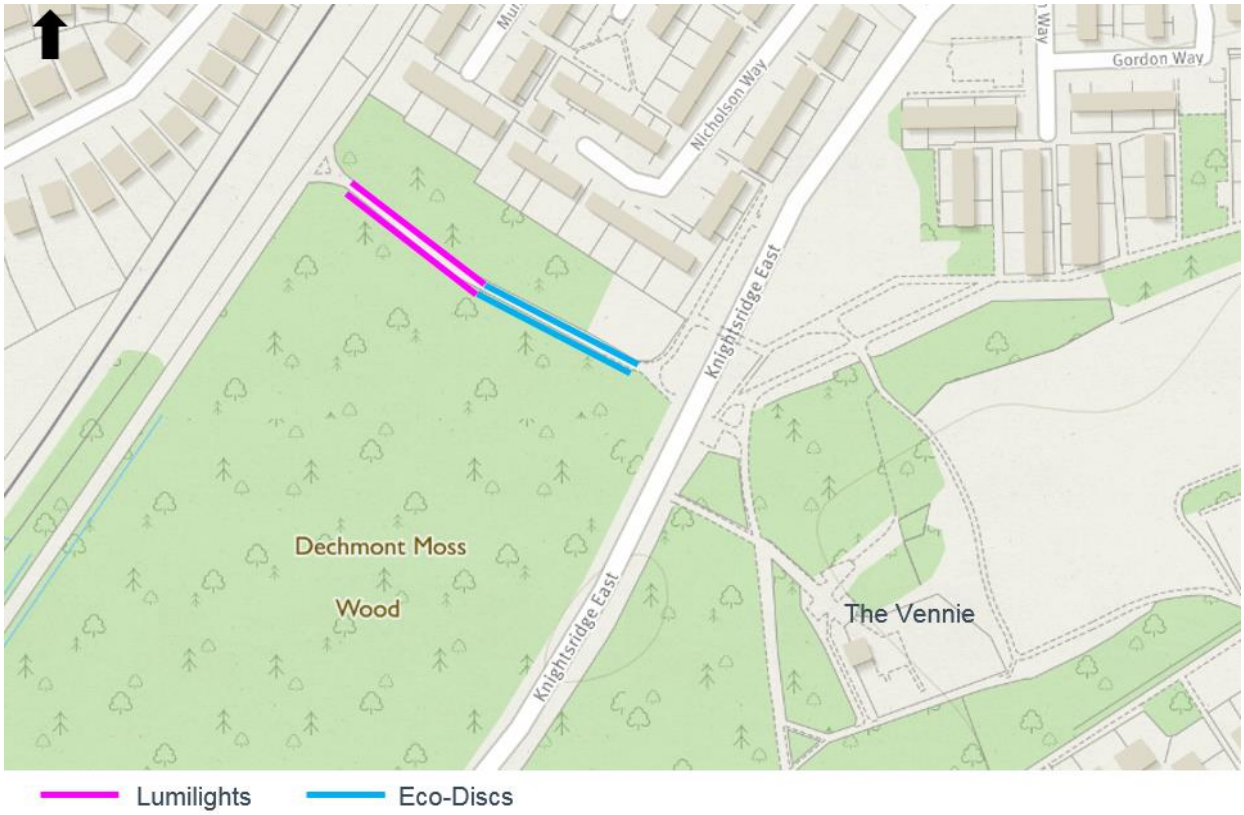


Figure 5-6 Eco -Disc

Figure 5-7 Lumilight

5.2. Installation

Installation took place on the 10th and 11th of October 2017. The weather was predominantly dry with light showers and an approximate temperature of 10 °C. Installation of the 2 types of disc was quick and simple taking 2 days for a 4-man team to install 600 discs. The equipment required to install the discs was compact and therefore there was no need for path closure during the installation, warning signs were provided to advise pedestrians of the works. The only difference in installation between the Eco-discs and Lumilights was the diameter and depth of the core due to the differing diameter and depth of the discs.

The installation took the following steps (Figure 5-8 to 5-13):

1. Location of discs were marked onto the path using chalk and a tape measure at 3metres centre to centre.
2. Marked out locations were cleaned of dirt and debris using a brush and leaf blower and dried out using a blowtorch to heat the ground surface.
3. A core drill powered by a small generator was used to core out a cylinder 2-3mm larger than the diameter of the disc to the required depth.
4. A blow torch was used again to dry out any pooled water from the cored-out area.
5. Resin was applied to the cored-out area and the disc was placed on top with additional resin added to seal the surround if required.
6. The resin dried within 3-4 hours, sealing the discs in place.

Figure 5-8 Step 1&2

Figure 5-9 Step 3

Figure 5-10 Step 4

Figure 5-11 Step 4

Figure 5-12 Step 5

Figure 5-13 Step 6

5.3. Monitoring

After installation, the trial locations were visited 3 times over a 4-month period. The final visit coincided with a visit to The Vennie to discuss the project with the members and to gather feedback and opinions on the effectiveness of the installations. The feedback from The Vennie members who experienced the entirety of the process from engaging in the X -Route report to seeing the culmination of the Star Path Lights installed was very positive. They were very happy that they could see a physical result from their participation in the earlier report and would be encouraged to participate in similar workshops in the future. In addition, a Facebook page was created and linked to the youth club page to gather responses from the wider Livingston community. However, this was not widely used and therefore the conclusion below focuses on the feedback of The Vennie members.

6. Conclusion and Recommendations

6.1. Progress

In the 4 years since the CH2M Glowing Roads report one additional example of glow in the dark pathways has been found. Apart from the Netherlands Glowing Road project deteriorating in adverse weather, there is little or no data available for the effectiveness/ design life of these and many of the installations are supplemented with the use of LEDs suggesting that the technology has not progressed significantly since 2014. However, with companies like PRO-TEQ installing more pathways such as the recent 2017 example in Shanghai there may be further information on the effectiveness of these type of installations in the near future.

Several products which provide 'glow in the dark' features (but do not cover an entire path) are available to purchase and in this respect progress has been made. There appears to be a growing market for glow in the dark products with many press articles and websites dedicated to these and their potential applications.

6.2. Effectiveness

6.2.1. Product

Three site visits were undertaken to ascertain the effectiveness of the Eco-Discs and Lumilights in terms of visibility, the 'glow' emitted and any requirement for maintenance.

When walking or cycling down the path 3-4 discs could be seen in front of the user meaning that the path was delineated for approximately 12m ahead. Figures 6-1 to 6-4 show the installation at Trial Location One. Although this location was chosen as it was unlit there was some ambient light at either end of the pathway. The perception was that the products would not be strong enough to entice someone who was not planning on using the path to use it, as the light seen when transitioning from the ambient light to the dark was not particularly strong. However, once in the dark the products appeared brighter and clearer meaning that a user who was intending to use the dark path anyway may benefit from the delineation to mark the edge ways. When compared to a conventional solar LED which can be seen from approximately 500m the glow emitted from the trial products was not comparable.

Figure 6-1 Site Vist One (DSLR Camera)

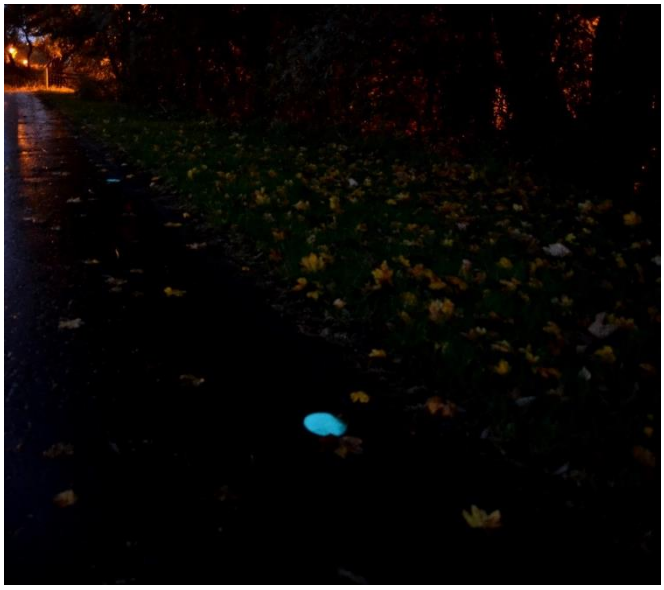


Figure 6-2 Site Visit One (DSLR Camera)

Figure 6-3 Site Vist Two (Phone Camera)

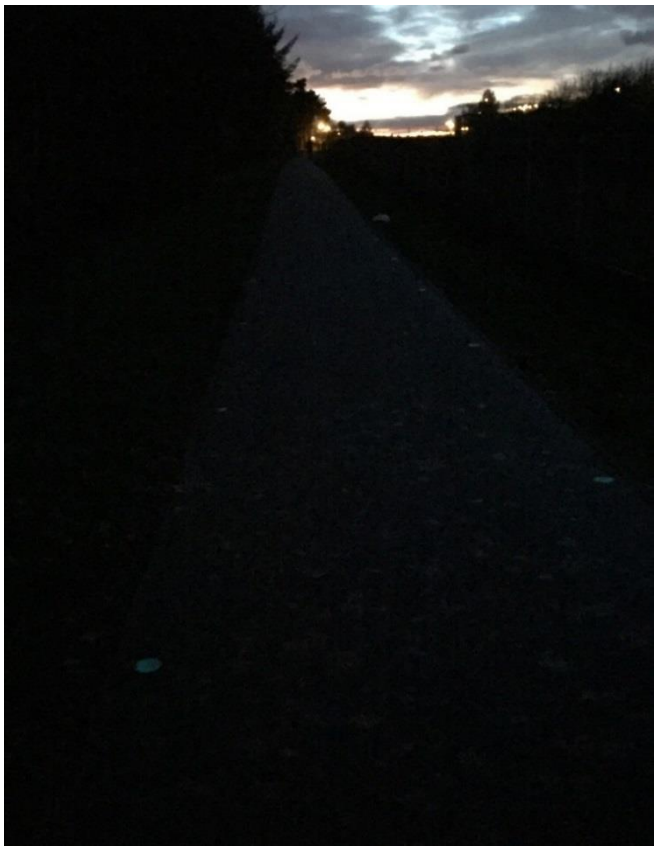
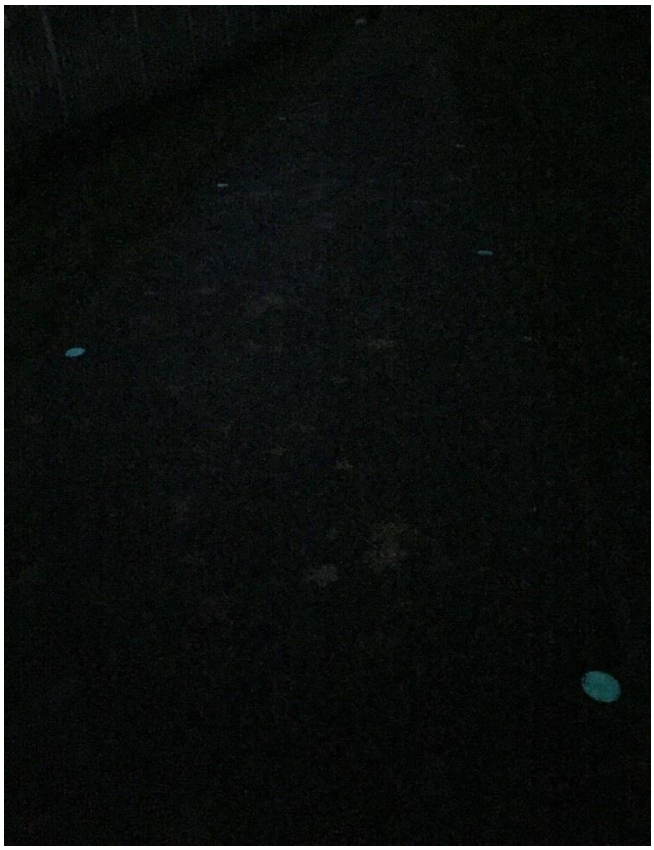


Figure 6-4 Site Visit Two (Phone Camera)



The three site visits took place over a four-month period from October to February and during this time the perceived effectiveness remained the same i.e. the 'glow' emitted did not diminish due to the severe Scottish weather nor did it get any brighter the longer it was exposed to sunlight. In addition, no materials were stolen or damaged throughout the evaluation period. Some dirt and foliage did gather on the discs as expected but not enough to be detrimental to the delineation of the path. The main factor contributing to this appeared to be if the discs were slightly recessed or slightly protruding from the path. Figures 6-5 and 6-6 show the additional dirt and foliage which accumulates when the discs are installed marginally below path surface.

Figure 6-5 Protruding From Surface

Figure 6-6 Recessed into surface

When determining the difference between the Lumilights and Eco-Discs it appeared that the flat surface Lumilight was marginally brighter than the textured Eco-Disc but this was difference was not substantial enough to make any difference to the number of discs that could be seen ahead of the user. In addition,

the flat surface Lumilight appeared to accumulate more dirt or the dirt seemed more noticeable than on the ridged Eco-Disc. Overall the difference in these two factors was very small and therefore it is suggested that the products are equally effective.

Feedback and discussion was undertaken with members of The Vennie to determine their opinion on the effectiveness of the products. The feedback session took place on the third site visit and had roughly 10-12 attendees. The feedback received on the effectiveness of the 'glow' was predominantly positive. The main thoughts were that the discs produced a 'cool' colour and 'stylish' effect and but that they would be better if they could be improved to be brighter than they currently are. Two attendees suggested that they had walked along the path at dusk time and that they didn't notice any light, confirming that ambient light is detrimental to any effectiveness perceived. Most of the attendees agreed that they could be more effective in rural locations where there is no ambient light but did propose that the amount of people who would cycle in total darkness would be low.

6.2.2. Location

Out of the two trial locations, the Eco-Discs and Lumilights in Location One charged with direct sunlight appeared more effective, glowing brighter than those at Location Two which are under a tree canopy. Figures 6-7 and 6-8 show a comparison of the 2 locations on site visit one. However, Location Two although dark in some areas does have considerably more ambient light and when the discs were covered by shadow they did glow as shown in figure 6-9. This suggests that the discs may charge in UV light as well as direct sunlight however ambient light hinders the effectiveness considerably.

Figure 6-7 Trail Location `One

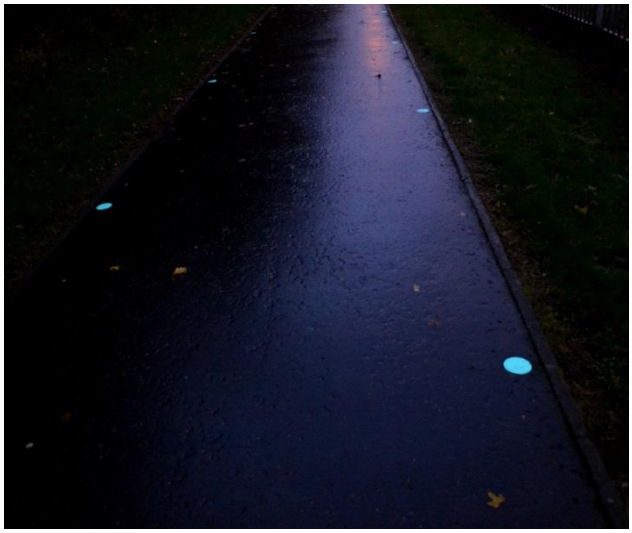
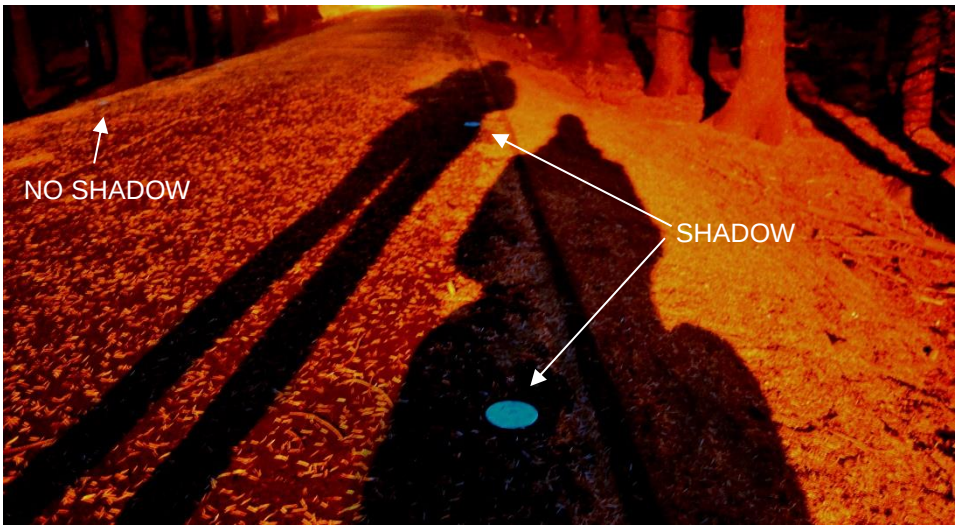


Figure 6-8 Trial Location One

Figure 6-9 Trial Location Two (Shadow)



6.2.3. Effect on active travel use

Feedback from majority of The Vennie members was that if these lights or solar lights were installed in other locations or on larger scale than one path then, they would be encouraged to cycle more and use cycling as a transport method as the lights would be a cool design feature that they would benefit from using. Unfortunately, the trial products were not bright enough to overcome the reputation of the dark paths in Livingston in the short time available for this trial. However, feedback shows that overall the scope to use innovative lighting features to encourage active travel would be a successful one.

6.3. Recommendations and next steps

Overall the Eco-Disc and Lumilights are good quality products provided by competent suppliers.

The installation into bound pathways is straightforward and quick and the option to install onto posts or bollards make them applicable to pathways with unbound conditions. The installation into the path surface minimises any trip or slip hazards and has insignificant effect on path drainage while the small makeup of the products ensure that path surfaces are not affected detrimentally if the products were to be removed.

In order for the most effective installation the discs should protrude from the carriageway by 1 to 2mm in order to lessen dirt build up on the discs. The ‘glow’ emitted by the products is more effective in very dark conditions and ambient light is detrimental to the light emitted. When ambient light reaches a certain level, the products become ineffectual.

The low cost of the products (Eco-Disc in particular) make it an attractive proposal when trying to delineate pathway edges compared to a solar LED which can cost more than ten times the price of Eco-Discs for a basic model. Our recommendation is to use this product in conjunction with solar powered LEDs. This would minimise the number of the more expensive LEDs required but give the benefit of the brighter technology. This is currently being considered on the A9 Dualling scheme for non-motorised user routes in rural areas where there is no ambient light. If this was to go ahead it would allow better understanding of how effective the lights would be in a rural dark setting. A campaign of publicising and signing these paths would help to increase user confidence.

Appendix A. Findings and Recommendations 'Glowing Roads' Report

A.1. Findings

After extensive research using the internet, the only product listed as a glow-in-the-dark road marking paint was the Dutch innovation. It was not apparent from the research that other road marking companies were developing a glow-in-the-dark road marking product.

Latest findings on the Dutch glowing paint road markings suggests that it is currently being tested in laboratory conditions and the intention was that it would be road tested in Brabant, Holland in mid- 2013. A later article suggested however that this date had been extended until mid-2014.

The glow-in-the-dark paint uses strontium aluminate pigments that can glow throughout the night on a single charge. The resulting paint discharges eight to ten hours of glow. The charging of the paint occurs during the daytime. The idea is therefore to provide the road marking in areas where there is no public lighting. It is considered to be a simple, cost effective measure compared to using a combination of existing road markings and street lighting. A particular benefit is expressed by the Dutch because of its approach to sustainability, where lighting is shut down at night to save money.

The initial cost of putting the glowing road marking paints onto urban roads would of course be very high but the Dutch expect that long-term savings could be found through the removal of road signs and markings that require costly electric powered lighting to be visible at night. The interest of such road marking paints in countries where electricity fails regularly, such as India and Africa, has increased.

Laboratory work is assessing aspects such as skid resistance and its ability to withstand salt ingress.

A.2. Limitations

Using modern grade strontium aluminate pigments may allow the glow to be bright enough for the first two or three hours. However, once the daylight fails, discharging will begin and therefore by the time the sun fully sets the glow-in-the-dark road marking paint may actually only glow for an hour or so.

Furthermore, the headlights from cars may recharge the paint but the headlights themselves will also put out an ambient light that is likely to overpower the glow. The Dutch considered that the road marking paint might be an alternative to cat's eyes. However, the length of discharge from the glow would have to be proven to provide sufficient light throughout the hours of darkness.

In the UK there are a number of specific documents which govern the use and performance of road markings. These are related to luminance, reflection under vehicle headlight, colour, skid resistance and functional life. The durability of road marking materials depends upon three factors: traffic volume, materials used and thickness. Standards and specifications restrict the thickness and width of road markings so manufacturers produce materials to meet traffic volumes and standards/specifications.

Following the strict guidelines for testing, a road test certificate for each product is required and road tests need to be carried out.

The road markings standards and maintenance requirements in the UK have consistently remained lower than those accepted in Europe and the US for some years (Ref: Road Markings, Road Safety and Efficient Road Utilisation in 21st Century Britain, Road Safety Markings Association, 2007). If new products come to the fore whilst experiencing the current increased traffic levels, a change to road markings to a higher standard may take some time. Nevertheless, innovative products such as glowing road markings could be considered a sustainable option with a low carbon footprint once they had been tested and provided they can meet strict performance criteria set out in the standards/specification.

The study has shown the potential for glow-in-the-dark paint for road markings. However, this research concludes that they are very much in the early stages of development and it is not yet clear if trials have

been carried out with which to gauge their success. The information available to date has been very limited and UK road marking paint manufacturers do not seem to have expressed an interest to date.

A.3. Other Developments

The research showed that in the UK, “Starpath” is a glow in the dark quick drying, spray applied elastomeric coating manufactured, supplied and traded by PRO-TEQ. The coating can be combined with stone to create a non-slip pathway, or with rubber crumbs to re-surface a playground. A meeting was held at the PRO-TEQ offices on 7th February 2014 to discuss the concept of glowing road markings and the “StarPath” product. PRO-TEQ are the sole suppliers, contractors and traders of their product. It uses a mixture of a photo-luminescent powder with a stone or rubber aggregate which is placed on to a polyurethane layer. It is finished with a clear polyaspartic sealant topcoat. The aggregates can be varied in size and colour. Total thickness of the system is 4-5mm. “StarPath” can be placed over concrete (sealed), cardboard, metal and wood. It is non-reflective, waterproof and anti-slip. PRO-TEQ claim at least 16 hours of discharge because it absorbs UV light rather than direct sunlight. The photo-luminescence adjusts to the natural light. Therefore, if it is pitch dark then “StarPath” will be brighter. If the sky or lighting conditions are lighter, then the luminsence will not be as intense. PRO-TEQ claim that it is environmentally friendly.

“StarPath” was spray applied with specially designed spraying equipment on 1,600ft^2 of existing tarmac footpaths at Christ’s Pieces Park in Cambridge in 2013. The spray application operation took 4 hours and was ready to open to the public after 30 minutes of the work finishing (Ref: www.independent.co.uk/life-style/gadgets-and-tech/news/StarPath). It has anti-slip properties and is non-reflective.

PRO-TEQ believe that it could be applied to tarmac on roads. A fine white aggregate is available if it was to be developed for use in road markings.

PRO-TEQ claim that tests in NAMAS accredited laboratories are complete. It was considered at the time that further testing would be required to investigate skid resistance, salt ingress, maintenance, temperature sensitivity, wear and abrasion etc. However, if these tests have already been successfully completed, then it adds credibility to the products viability as a photo-luminescent footpath/surfacing product and demonstrates that there may be potential in supporting further development of the technology as a road marking product

A.4. Summary

Currently, the innovation of glowing road markings is not as developed as first envisaged. There is no historical background data available of the trial set with the road users’ organisation along a short stretch of provincial road in Brabant, the Netherlands, originally planned for November 2013. A recent search suggests that this has been put back to mid-2014.

In the UK, a glowing footpath/surfacing product, “StarPath”, manufactured, supplied and contracted by PRO-TEQ, has been put down on a number of cycle ways and footpaths from 2013 and is seeing a rise in publicity and potential applications. “StarPath” is not a road marking paint. It is an aggregate-powder mixture which has a sealant topcoat. However, there is clearly potential for the development of a road marking product using similar technology.

A.5. Considerations

For a road marking product to be considered, it would have to be developed, and tested to prove that it meets all European and British Standards. As such, the product would have to demonstrate performance and durability against all of the following criteria:

a) Standards
- In particular, BS EN 1436 which is based on functional life, luminance in daylight, luminance in dry, reflection under vehicle headlight, colour and skid resistance,
- TD 26/05 is also important in terms of setting out the minimum maintenance requirements for retro- reflectivity, luminance, skid resistance and wear.

b) Performance
- Skid resistance,
- Luminance,
- Reflection under vehicle headlights,
- Charging/discharging cycles vs full range of daylight hours under Scottish conditions.

c) Durability
- Minimal maintenance requirements,
- Durability with respect to traffic volumes.

d) Sustainability
- Materials and carbon footprint.

e) Economics
- Whole life costing.

A.6. Next Steps

As a generic concept, “StarPath” could potentially be developed for use as a road marking product. The next step will be assessing its potential application to tarmac on roads and the consequent testing (both laboratory and trial sections of road) to determine if it meets the required British and European Standards.

SRRB and Transport Scotland should consider options for providing further support to the development of this emerging technology. Whilst the product development is likely to require to be led by the private sector, there is an opportunity for support to be provided in terms of further material research and laboratory testing.

Appendix B. X-Routes Report – Findings and Actions

B.1. Information & Knowledge

Young people didn't see cycling as a mode of transport. They were keen to be made aware of active travel routes in their area and support services and schemes to get young people into cycling. They felt that in order to become a commuting cyclist there was a certain level of knowledge and skill that they would need to develop over time.

Young people don't recognise the term 'Active Travel'.

B.2. Social Barriers

For a young person to develop an interest in cycling the biggest factor is having a positive social influence close to them, this could be an advocate in the family, friend, school or in the community. Cycling was described as a niche interest and that there needs to be enjoyment and a social aspect for a young person to develop a sustained interest. Negative social influences were also raised with cycling being seen as 'clique' and bullying based on being part of a group or based on your skill or equipment.

It was apparent that cycling was seen as a physical activity and became something that teenage girls were less likely to do. Young people's social perception of cycling has raised questions around how cycling can be made more accessible and desirable for young people.

B.3. Common Barriers

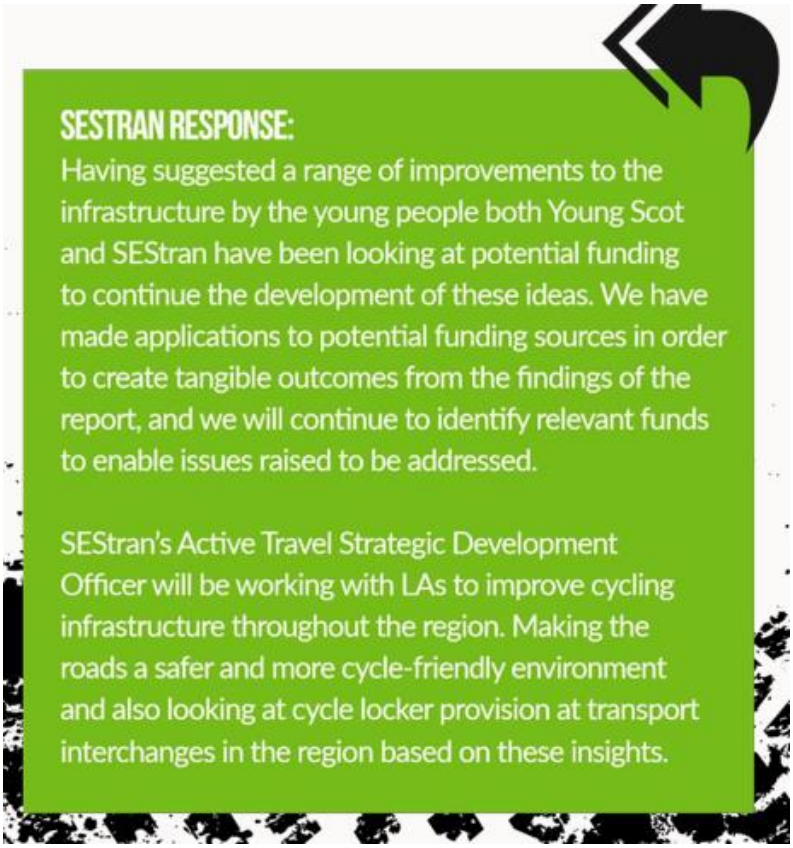
Across the project it was apparent that young people face many of the same barriers as adults. Ideally young people want their journey or commute to be safe, available routes away from traffic to encourage regular travel, cycle lanes that are clearly separated from traffic, these routes are well maintained and have decent visibility and there are accessible storage and support facilities for those travelling by bike.

B.4. Quality of Routes

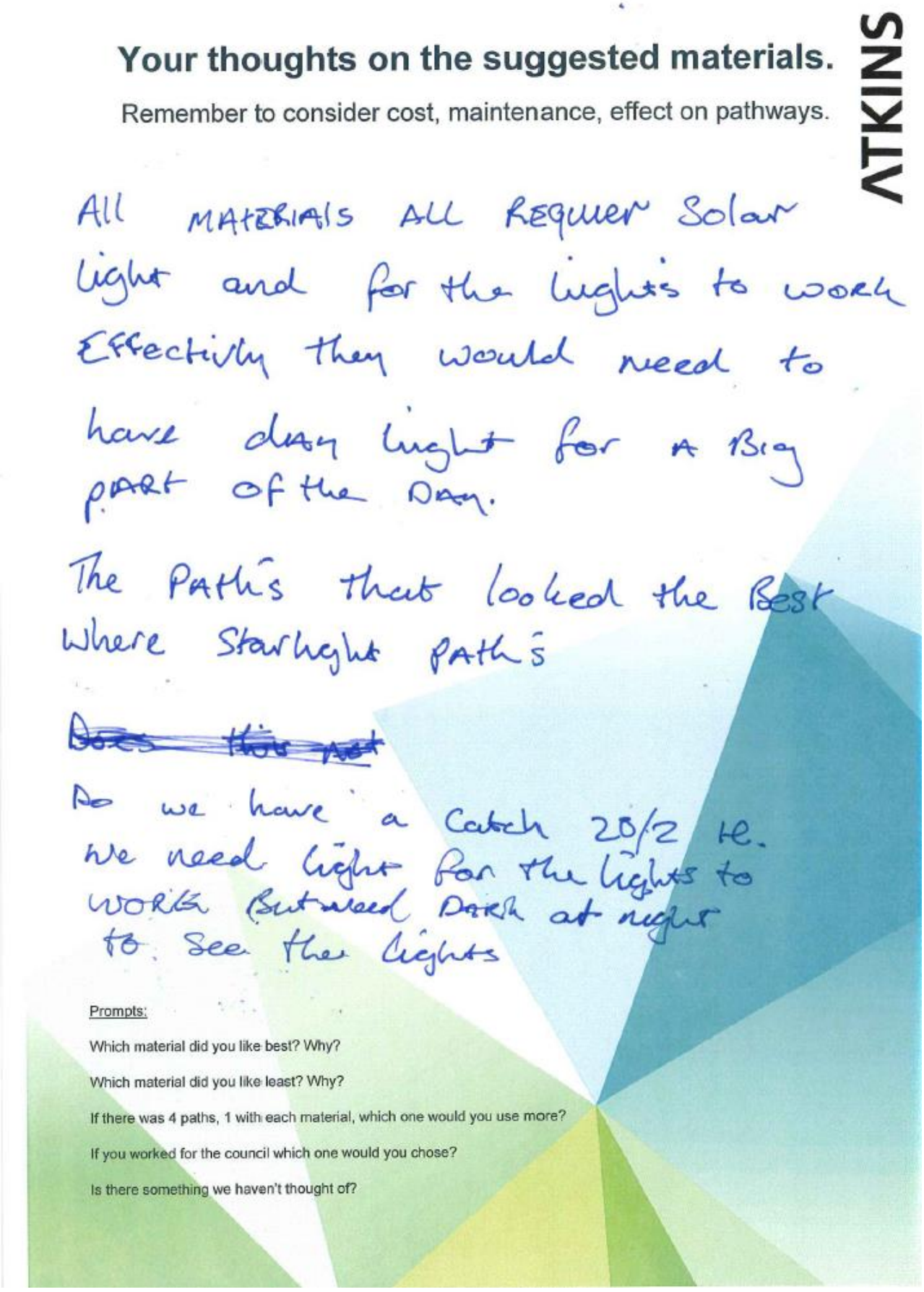
The Vennie participants shared, "In Livingston you can get around without needing to cross a road" and expressed how useful the underpasses were. They had an issue with the state of the paths, finding that there was also a lack of lighting and areas of overgrowth which reduced their visibility making the experience nerve-wracking.

One pitch suggested that lighting was important to make young people feel safe on off road paths, they wanted to see more novel approaches to this by making the lighting blend in with the surroundings either through hanging in natural features or making the path itself glow using either cat's eyes, solar lights or luminous paints.

B.5. Conclusion



Appendix C. The Vennie Feedback on Materials (Example)



ATKINS

Your thoughts on the suggested materials.

Remember to consider cost, maintenance, effect on pathways.

All MATERIALS ALL REQUIER Solar light and for the lights to work Effectivly they would need to have day light for A Big part of the DAY.

The PATH's that looked the Best where Starlight PATH's

~~Does this not~~

Do we have a Catch 20/2 he. We need light for the lights to work But need DARK at night to See the lights

Prompts:

Which material did you like best? Why?

Which material did you like least? Why?

If there was 4 paths, 1 with each material, which one would you use more?

If you worked for the council which one would you chose?

Is there something we haven't thought of?

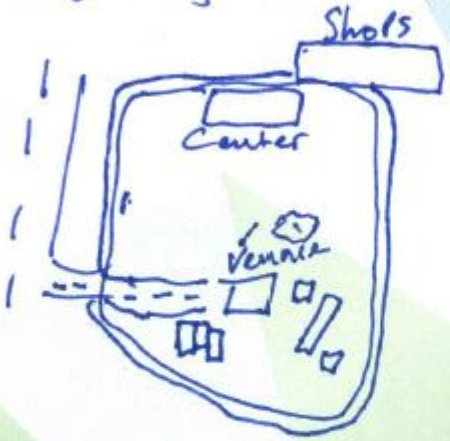
Appendix D. The Vennie Feedback on Trial Site (Example)

Your thoughts trial site.

ATKINS

Remember the criteria: Local, Easy to Access, Surfaced Path, Useful Links, Will benefit from lighting guide.

there is A Path just at the Side of the vennie witch Connects vennie to the Shops and Shops to the Community center and center to the School School around to bus Stops and Back to the vennie.
this Path fits with criteria, Local, EASY ACCESS, Surface of the Path Links this Path will Benifits from lighting Good Trial Path!!!



Key
- Buildings
- Road
- Path
- PARK

Prompts:

Use the large maps to highlight useful Links: Schools, clubs, parks, shops, community centres etc.

This will help to focus on possible trial paths in-between.

Please include the path name/ description of location and why you suggested the particular path(s)

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