Evaluation of night-time path delineation treatments

Prepared for Department of Transport and Main Roads

CDM RESEARCH

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Executive Summary

There are locations on the shared path network where overhead flood lighting for night-time visibility is inappropriate for local environmental or cost reasons. In these situations, there are few alternatives which provide improved edge delineation of paths in low-light conditions. The purpose of the present evaluation was to consider the possible benefits of two treatments:

- solar powered stud lights incorporated into the path pavement, and
- glow-in-the-dark surface coatings that luminesce during night-time.

Short sections of these treatments were installed along a new section of shared use path along the Ferny Grove to Samford Cycle Link. In order to assess the possible benefits of these treatments night-time riding trials with 16 experienced bicycle riders were undertaken. The key findings from these trials were:

- Both treatments were very well received by riders. The riders universally supported much more widespread use of these treatments on unlit paths.
- The majority of riders had only a slight preference for one treatment over another, and the sample of 16 riders was fairly evenly split between those who preferred the stud lights (7 riders) and glow-in-the-dark paint (9 riders).
- Although conditions during the trial were dry, riders were concerned about the possibility the glow-in-the-dark paint would be less visible when the path surface was wet given that water will tend to reflect light. It was felt this level of deterioration would not be as great with the stud lights.
- It was observed that the glow-in-the-dark paint was very conspicuous in complete darkness and contrasted well against the path and surrounding vegetation, all of which appeared entirely black. However, the contrast was reduced when a headlight was used and particularly more powerful lights which tended to create a "washed out" scene.
- The prevailing view was that the use of a centreline at corners (and only at corners) was an appropriate design response. Riders noticed the centreline was brighter than the edgeline, which is as expected given the use of reflective beads within the centreline.
- There was a preference for the stud lights to be close together to have optimal effectiveness.
- For many riders the longevity of both treatments were a cause for concern; some observed that other paths with stud lights in Brisbane had not been well maintained. The longevity of the glow-in-the-dark paint is unknown; riders expressed concern about how durable it would be in the medium to long term (although they also noted it would be less susceptible to vandalism than the stud lights).

It is suggested there is overwhelming support for wider use of these treatments, and that either treatment would be strongly supported by riders and be effective at reducing riding-

off-path crashes at night. Which treatment may be superior, and in what circumstances, is not entirely clear. However, we suggest the following general principles ought to apply:

- The longevity of the glow-in-the-dark paint will need to be demonstrated over a period of several years before it can be confidently recommended.
- The odour from the glow-in-the-dark paint is substantial, and appears to last several weeks after initial application. This may be an issue in built-up areas close to residences.
- Setting aside the caveat about longevity, either treatment may be appropriate on non-reflective dark pavements (i.e. asphalt) – we suggest cost ought to be a significant consideration given the similar technical performance of the treatments.
- In locations where there is some ambient lighting, perhaps from nearby buildings or streets, the stud lights may be more effective than the glow-in-the-dark paint.
- Away from all sources of ambient lighting the glow-in-the-dark paint may be a superior option, although it may still be appropriate to use stud lights selectively at particularly hazardous locations (such as near bridge abutments, bollards or other significant hazards on or near the path).
- When glow-in-the-dark edgeline is used this should be complemented with glow-in-the-dark centrelines at corners (and only at corners, at least on quiet paths).
- If stud lights are used for edge delineation it *may* be appropriate to use glow-in-the-dark paint as a centreline at corners, although it is suggested this may be seen as confusing and ought to be given further consideration.
- Incorporating reflective beads into the glow-in-the-dark paint is probably not necessary in most instances.

It is suggested that the main uncertainties remain the longevity of the glow-in-the-dark paint, the contrast of the paint when the path surface is wet and the conspicuity of the paint on light concrete surfaces.

1 Introduction

CDM Research was appointed by the Department of Transport and Main Roads to undertake an evaluation of treatments for shared use paths that improve delineation at night. Specifically, the primary objective was to evaluate the proprietary "moondeck" path coating system[1]. This system is a glow-in-the-dark surface treatment that is designed to provide luminescence during darkness. It should be noted that the treatment works by being luminescent, not by reflecting the light from external sources. In order to provide a baseline against which to compare this treatment a short section of solar powered stud lights[2] were also installed.

1.1 Purpose

The purpose of the study was to identify rider preferences towards night-time path delineation treatments that do not have the wider environmental consequences (or financial costs) of overhead flood lighting, but still serve to provide some level of path edge delineation. It is noted that the focus was on reducing rider crash risk; that is, reducing the likelihood that riders may fail to navigate a corner or drift off the path and in so doing fall from their bicycle[3]. Explicit consideration was not given to personal safety; that is, fear of assault. Neither of the trialled treatments are likely to offer any objective or subjective benefit in this regard.

1.2 Methodology

1.2.1 The path

The treated section of path was newly built in February 2016 and is a 3.0 m asphalt path extending over a distance of around 1.3 km from Lanita Road (Ferny Grove) to Lanita Court (referred to as the Samford Forest section) and another 0.4 km section from McLean Road to Petersen Road (the horse paddock section). The path offers a number of desirable characteristics for the present trial:

- There is almost no ambient lighting on the path at night; the path travels through forest (Samford Forest section) or farmland (horse paddock section) some distance from buildings and roads that would otherwise provide a source of ambient lighting.
- The path has a number of gentle curves and is undulating, creating situations where the rider may not be able to see far ahead and will be required to adjust their course.

[1] Strini Industries: http://moondeck.com.au/.

[2] Clearview Intelligence: http://www.clearview-intelligence.com/products/solarlite-f-series-flush-road-studs.

[3] It is noted that this crash mode may have significant consequences; there are documented cases of permanent, disabling injury and death resulting from riders leaving shared paths and falling from their bicycles. It is also recognised that many of these crashes occur during daylight hours and periods of good visibility, suggesting the issue is not simply of ensuring riders are aware of the presence of path edges but also ensuring that path verges are free of hazards. In practice, creating and maintaining a hazard-free verge is likely to be difficult or impractical.

- The presence of the forest precludes the use of overhead flood lighting, even if this were deemed cost effective, because of the presence of the sensitive natural environment.

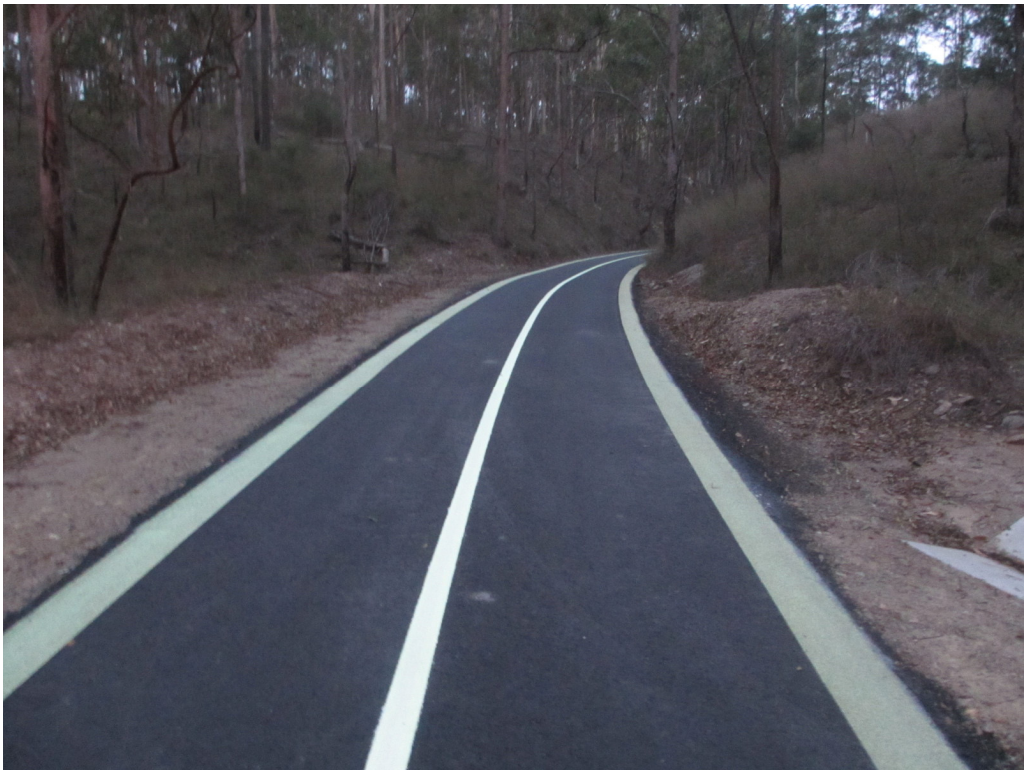
1.2.2 The treatment

The 1.3 km forest section of path was treated over most of most of its length with 250 mm moondeck edgeline on both edges of the path *and* 100 mm moondeck as a solid centreline at corners. The centreline also incorporated reflective beads. Over a short distance (around 60 m) at the Lanita Road end of the path solar stud lighting was installed on both sides of the path at approximately 10 m longitudinal offsets. The horse paddock section consisted of 150 mm moondeck edgeline over the southernmost 100 m length and stud lights over the remaining section.

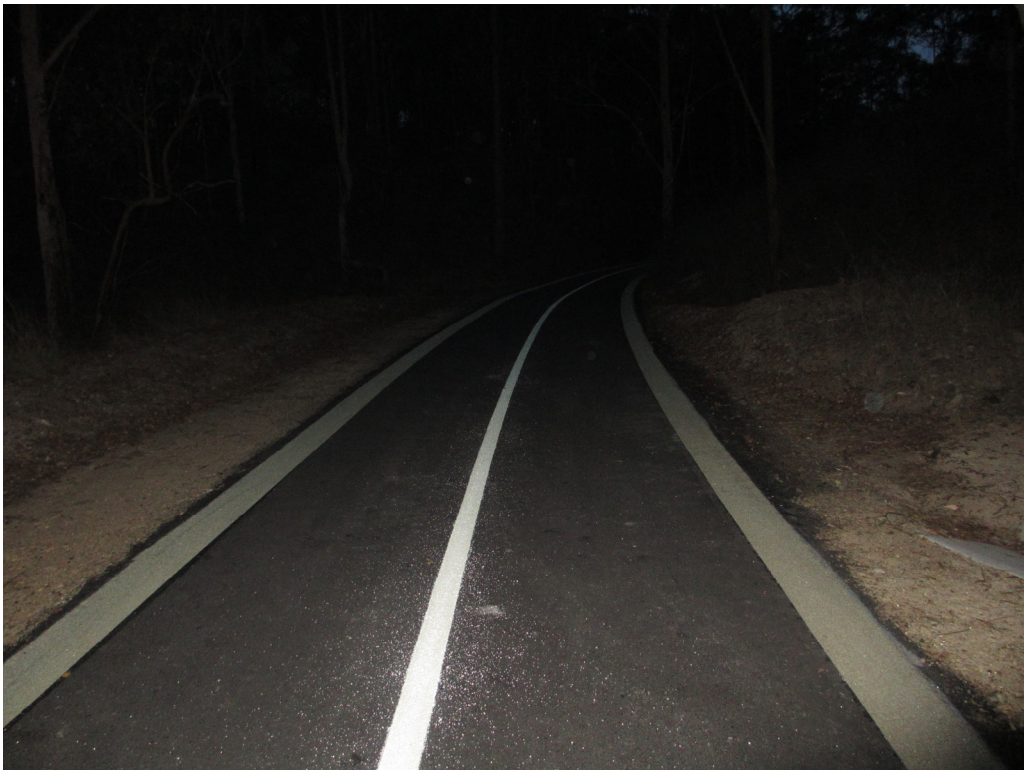
Images of the moondeck installation are provided in Figure 1.1. We make a number of observations about these images:

- The moondeck is visible during daylight and twilight, and has a slightly greenish tinge.
- The centreline is slightly whiter in appearance (both under natural and artificial illumination), probably as a result of the reflective beads used for this line.
- While the twilight image fairly reflects how the human eye sees the treatment the night image does not accurately portray how the treatment is seen. In reality, when the scene is lit by a headlight the path takes a somewhat more washed out appearance, detracting somewhat from the contrast of the moondeck on the black pavement. Alternatively, when no forward lighting is used (and the eyes are given time to adjust to the dark scene) the moondeck is clearly visible in an otherwise black scene for as far as the path view is unobstructed (rather than diminishing as suggested by this photo).

The stud lighting is shown in Figure 1.2. Setting aside the motion blur and camera focussing issues in these images these images reasonably portray how the human eye sees the stud lighting. In the completely unlit scene the lights would extend off into the distance as a clear “runway” while under illumination they remained clearly visible, even with powerful headlights.

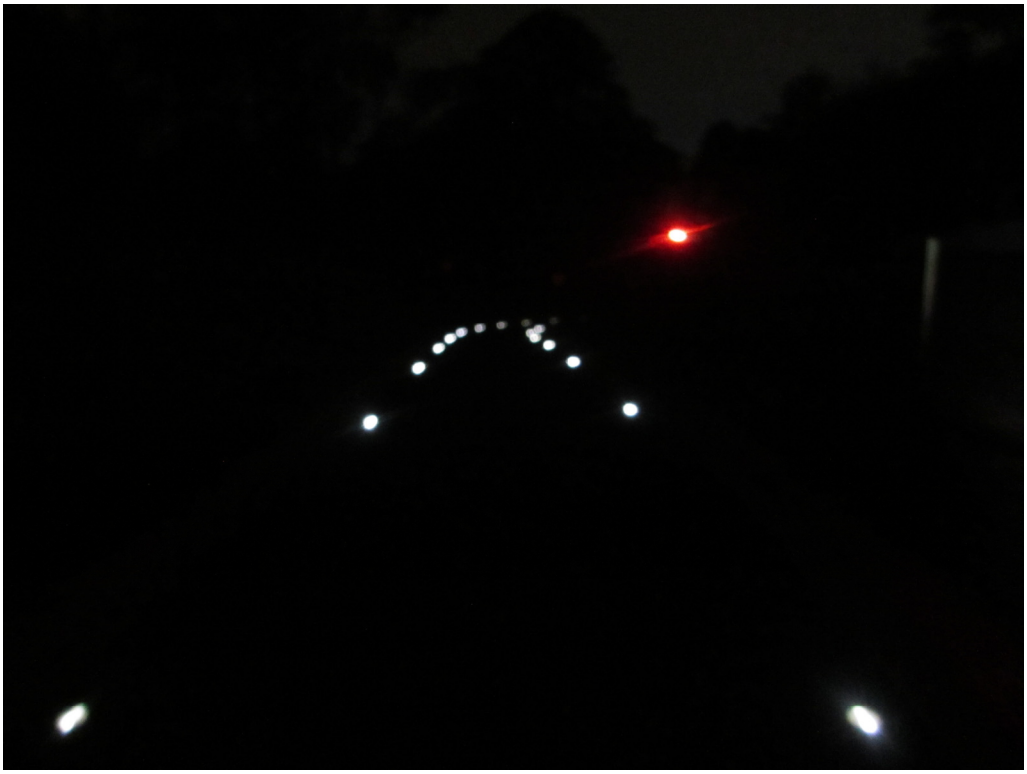


(a) Dusk condition with camera flash (note reflectivity of centreline)

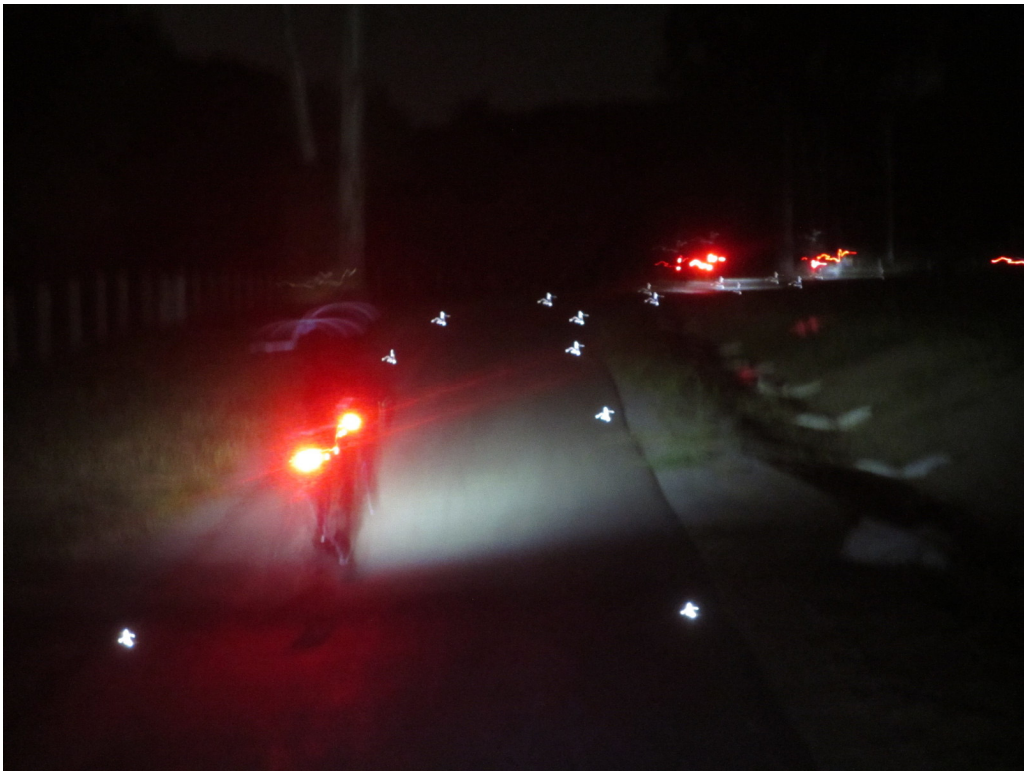


(b) Night time condition with camera flash

■ Figure 1.1: Glow-in-the-dark linemarking



(a) No headlight



(b) With headlight

■ Figure 1.2: Stud lighting

The trials described in this report occurred around two months after the treatments had been installed[4]. As such, it seems reasonable to expect they would be operating to their optimal level and not to have significantly degraded since installation. Conversely, we cannot make statements as to the durability of the treatments.

1.2.3 Trial methodology

The methodology adopted was a supervised trial using volunteer bicycle riders. Riders were self-selected volunteers recruited via facebook and twitter social media posts via the Brisbane CBD BUG. The content of the post used for the recruitment is provided in Appendix A.

A total of 16 riders were recruited, all of whom could reasonably be described as experienced and confident bicycle riders (Section 2). The trials were conducted on the evening of Tuesday 10 May 2016 when weather conditions were fine, mild and dark[5]. The day itself was partly cloudy and warm (28°C) such that the both the solar powered lights and glow-in-the-dark treatments could be reasonably be expected to be "charged" to a sufficient extent.

After a safety briefing riders were provided with a short description of the purpose of the trial. Detailed descriptions of the treatments were explicitly avoided to reduce the likelihood of influencing the results. Instead, riders were informed only that TMR "… is trialling treatments to improve the visibility of paths at night…". After the introduction riders were asked to travel across the full 1.3 km forest section of the path (covering both stud lighting and glow-in-the-dark treatments) one at a time, and around one minute apart. In so doing the intention was that riders would experience the path at night with only their own bicycle lights to illuminate the path.

Upon reaching the western end of the treated section at Lanita Court riders were individually subject to a short interview asking whether (a) they had noticed either or both of the treatments, and (b) if they had noticed them whether they felt more "comfortable" riding along the path.

Once all riders had reached the western end of the section, the group were escorted to the horse paddock section and riders were again asked to ride individually across this section. One rider positioned their bicycle on the path facing oncoming riders (with their headlight on) to simulate a meeting event.

[4] The centreline was only installed two to three days before the trial. It is understood from the product manufacturer that the material can take some time (in the order of several weeks) to fully "charge". However, in practice the centreline appeared to glow to a level not dissimilar to the edgeline which had been installed two months earlier. The horse paddock section was treated only a few days before the trial; we suggest the observed ineffectiveness of the 150 mm edgeline here could be attributable to the lack of sufficient time having elapsed since installation.

[5] The moon phase was 18% visible on this evening, such that this condition represents among the "worst" cases for background illumination. There was partial cloud coverage, which tended to provide marginally more illumination than would be expected to occur in clear conditions.

Finally, all riders were invited to share their qualitative thoughts on the absolute and relative effectiveness of the two treatments. These thoughts form the basis of the discussion that follows in Section 2.

2 Results

2.1 Rider demographics

Riders were predominantly male (14 of 16) and adults aged under 50 (14 of 16). The sample is almost certainly biased towards more experienced, confident riders; five reported riding most days of the week and a further seven ride at least twice a week. As noted in Appendix B this bias towards experienced riders was a pragmatic decision and one that we suggest does not necessarily limit the transferability of the results:

- night-time riders are likely to be more experienced and confident than “average” riders, particularly in outer suburban locations such as this, and
- the visual and cognitive limitations of this sample are probably not dissimilar to the wider rider population, or at least not to those of good physical health.

Just over half of the sample (nine riders) report riding on unlit paths at least once a week. Just under half of the sample (seven riders) report being short sighted.

2.2 Rider opinions

The riders expressed strong support for both treatments compared with no night-time edge delineation. Riders generally felt both treatments achieved their objective of providing good visual delineation of the path edge. There was no consensus as to which of the two treatments were superior; seven riders indicated a preference for the stud lights while nine indicated a preference for the moondeck. When asked to score each treatment on a scale from one (“very poor”) to ten (“excellent”) the average score for the stud lights was 7.5 (median 7) and 7.4 (median 8) for the moondeck. Furthermore, most riders assigned both treatments scores within two levels of one another. Only one rider assigned a difference of greater than three; this rider giving a ten to the stud lights and four to the moondeck. Overall, we suggest that both treatments were viewed favourably and to a similar degree.

The qualitative discussion raised a number of issues for consideration. The general nature of these issues are summarised in Table 2.1 and the most pertinent issues are further described below.

■ **Table 2.1: Advantages and disadvantages of each treatment**

Treatment	Advantages	Disadvantages
Stud lights	• Very good edge delineation • Visible far ahead, provides advance warning of curves and climbs • Easier to see path in peripheral vision	• Vandalism susceptibility • Concerns over longevity (reference to other paths with poorly maintained stud lights)
Moondeck	• Good edge delineation • Provides a continuous edgeline, unlike the stud lights • Very good for pedestrians and riders without lights • Centreline delineation at corners • More resistant to vandalism • May better warn riders of the presence of hazards such as fallen branches than the stud lights	• "Washes out" under high illumination • Concerns over longevity • Concerns about toxicity of odour from treatment

2.2.1 Longevity and maintenance

Many riders raised concerns about longevity of both treatments. In the case of the stud lights these concerns were primarily around the risks from vandalism and the longevity of the electrical hardware. A number of riders referred to other paths in the Brisbane area of which they are aware where stud lights have been installed but have been observed to have failed and been seemingly neglected.

Given the absence of long term experience with the glow-in-the-dark paint it can only be speculated as to the longevity of this treatment. However, the riders speculated that the treatment will deteriorate, particularly in the presence of leaf litter and debris in the forest.

2.2.2 Odour

The glow-in-the-dark paint had a distinctive smell which lingered several weeks after application. A number of riders who used the path regularly, and who had ridden along the path immediately after the initial application, reported that the smell was very pungent. While this odour may not be toxic it would be likely to lead to concerns from neighbours should it be applied in built-up areas.

2.2.3 Headlight strength

The trial riders generally had headlights of high brightness; that is, they were capable of illuminating the path for a significant distance ahead of the rider. It was observed that all lights, but particularly the brighter lights, tended to illuminate the path surface in a light grey shade that was not dissimilar to the moondeck. This resulted in a "washed out" appearance that tended to detract from the conspicuity of the moondeck. Conversely, when no lights were used the moondeck stood out strongly from the black asphalt pavement; to the naked eye the scene consisted of almost-white edgelines contrasted against a black background (being the path and adjacent verge). It was observed that this situation provided a comfortable route to follow *without* any headlight, and – arguably – provided equivalent or better forward visibility than with headlights on. While riding without a headlight would clearly be inadvisable (given that it will make the rider invisible to oncoming path users) this does suggest benefits to pedestrians, who will presumably be unlikely to have lights.

While stronger headlights tended to exacerbate the "washed out" effect it was speculated that a similar deterioration in moondeck conspicuity may occur in built-up areas with extensive ambient lighting. In other words, moondeck may be most beneficial in areas with very limited ambient lighting (as was the case with the trial location).

It is speculated that this reduction in contrast of the moondeck under strong illumination may be greater for concrete pavements, which will presumably light up more brightly than the asphalt used on the trial path. As such, we would advise caution before applying the moondeck to concrete paths.

2.2.4 Visibility in adverse conditions

Conditions on the trial evening were fine and the path surface was dry. Riders speculated about the effectiveness of the treatments during wet weather, where the dominant view was that the moondeck would be far less effective under these conditions. The rationale for this view was the tendency for a wet pavement to reflect light which would tend to exacerbate the observed "washout" effect of the moondeck under strong illumination (Section 2.2.3). If moondeck were to be considered for wider use it is suggested that observations ought be undertaken during wet conditions at night to test this hypothesis.

Another consideration is that the luminescent material will presumably reduce its luminesce overnight as it "discharges". As the trials were conducted just after dusk the treatment was presumably operating optimally; it is not known how luminescent the material would be just before dawn. Again, this could be readily tested by visiting the trial site during the pre-dawn period.

2.2.5 Slipperiness

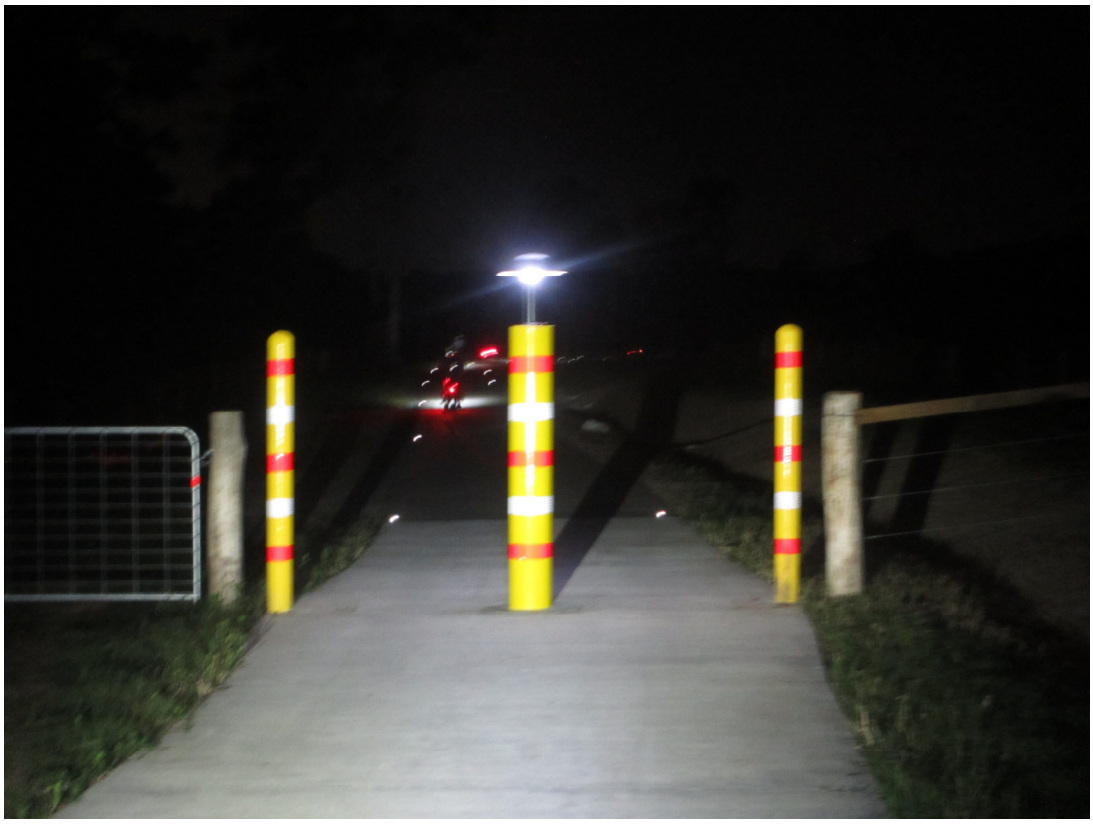
Riders discussed the likelihood that the treatments could present a slip hazard. The consensus was that the moondeck presented a minimal slip risk given that it appeared to have an abrasive finish. In this regard the moondeck was considered superior to many other paint products, and particularly thermoplastics, which present a much smoother finish that is more likely to be hazardous (particularly in wet conditions). Opinion was divided as

to the slip hazard presented by the stud lights; while it was generally acknowledged the smooth glass cover would be slippery it was also noted the surface area was small and riders would, in general, not need to ride directly over the light.

2.2.6 Pathside hazards

While not strictly within the scope of the evaluation, a number of riders commented about the presence of railings alongside the path at a number of locations. There was general concern that these may be insufficiently lit, most particularly at the start of sections of fencing and bollards on the path. While these did have reflective taping the visibility varied depending on the location of the rider, the vertical angle of the headlight and the horizontal spread of the headlight. It was suggested that in a number of cases the reflective tape was positioned high up on these obstacles whereas the lights generally deflect downwards such that taping towards the bottom of these obstacles may be more effective.

It was also observed that in the horse paddock section of path a single stud light was installed at the start of the fence alongside the culvert. This was found to be particularly effective. Similarly, there was strong support for the bollard with a light installed on top at the Petersen Road end of the trail (Figure 2.1). In all cases riders experienced concern about the presence of the bollards, and suggested that those at Lanita Court in particular were uncomfortably close together.



■ **Figure 2.1: Lit bollard at Petersen Road (note: photo taken with flash)**

2.2.7 Centrelines

The section of path with 250 mm edgeline moondeck also incorporated centrelines at corners. This centreline was both the moondeck and reflective beads in the treatment. This combination appeared to make the centreline appear somewhat whiter than the edgeline; this effect was evident both during the day and night (with and without illumination). Riders with more powerful headlights noted that the centreline stood out more than the edgeline. This, at least in part, probably serves to counter the "washed out" effect of powerful headlights on the standard moondeck treatment. However, riders generally felt this difference was fairly minor and inconsequential.

The other issue discussed with centrelines was whether they should be used at all. It was widely agreed that centrelines at corners are appropriate, but that on low volume paths such as the trial site centrelines are probably not appropriate on straight sections. The rationale for this view was that in such situations it is better to encourage riders to travel towards the centre of the path than towards the edges (and particularly at night).

3 Recommendations

The following recommendations are offered based on this evaluation:

- Greater use of night-time path delineation treatments is recommended, both because it increases rider sense of comfort and possibly reduces crash risks.
- The choice between the stud lights and moondeck is probably an issue of cost and longevity rather than performance *except* where (a) the path is concrete, (b) there is substantial ambient lighting, or (c) there are significant residential populations in the vicinity of the path. In any of these cases stud lighting is likely to be preferable to moondeck.
- The use of reflective beads in addition to moondeck is probably unnecessary.
- Centrelines should be used at corners but not on straight sections of low volume paths.

The following limitations apply to this evaluation:

- The longevity of both treatments was not evaluated.
- No consideration was given to personal safety; that is, risks of night-time assault.
- The effectiveness of the treatments in wet weather was not considered.
- It is unknown how well the treatments would work on light coloured concrete paths.

Appendix A: Recruitment post

The following post was made to the Brisbane CBD BUG facebook and twitter accounts by the administrator on 4 May 2016:

> The Department of Transport and Main Roads are trialling different ways of lighting paths at night. They're looking for volunteers to ride the new path through Samford Forest next Tuesday 10 May 2016 @ 6 pm. There's a $100 Coles gift card in it for volunteers. Registrations of interest here: <link>.

The post linked to another website with a form for entering the volunteers' name and email address, with the following description:

> The Department of Transport and Main Roads are experimenting with different ways of illuminating pathways at night. The Department has appointed a consultant (Cameron Munro of CDM Research) to undertake an evaluation of the treatment. In order to undertake this evaluation we'd like to invite bicycle riders to participate in night-time riding trials on the Samford to Ferny Grove Cycle Link in Ferny Hills.
>
> **When:** 6 pm, Tuesday 10 May
>
> **Where:** Lanita Road, Ferny Hills
>
> You'll need to bring your own bike with working lights. The trials will take about one hour and require riding back and forth along the path. We'll be looking for your feedback on the riding experience. You'll will be provided with a $100 Coles gift card as thanks for your assistance.
>
> To register your interest please submit your details below.

Appendix B: Rationale for methodology

The objective of the glow-in-the-dark treatment is to:

a) provide a sense of comfort ("reassurance") to bicycle riders at night as to the alignment of an off-road path, and

b) improve rider safety by reducing the risk a rider will drift off the path in darkness and fall from their bicycle.

In turn, we would hope to see an increase in night-time riders as a result of these improvements. Furthermore, from a relativist standpoint we want to see these objectives achieved with moondeck in a more cost effective manner than the alternatives (namely, stud lights or overhead lighting).

Self-evidently, the treatment should be measured by how well it meets the stated objectives. This in turn requires that at least some of the measures of effectiveness should be from the riders' perspective; even if the treatment were to be cost effective and easy to install and maintain from TMR's perspective, it would remain a failure if riders did not "appreciate" the treatment. We summarise what we see as the most obvious measures of effectiveness in Table B.1.

■ **Table B.1: Measures of effectiveness**

Measure	Method	Comment
Increase in night-time riders	Video count over multiple days	No "before" situation for comparison: the moondeck was installed at approximately the same time as opening the path. The absolute night time count is very low (in the order of 10 or fewer), and the effect of the moondeck probably small, such that the inherent variability in night-to-night counts will likely exceed the "signal" (i.e. the effect of the moondeck). Night periods are not fixed across the year; we would expect more riders at night during winter than during summer simply because of the shorter days. The only way to handle this effect would be to conduct the counts on days with comparable sunset/sunrise times. Video quality will generally be poor at night.
Rider comfort	1. Intercept survey 2. Trial riders: use a small	Likely low rider volumes, so very time consuming for few interviews. Small sample size.

Measure	Method	Comment
	selection of volunteer riders to travel along the path and offer their comments	Likely bias in the sample towards frequent, committed riders.
	3. Online survey	Conduct an online survey, showing segments of video from dark, moondeck and in-pavement lights and ask respondents to rate each option. Challenges in ensuring the video accurately portrays how the human eye sees the treatments.
Objective measures of visibility and light reflectance	Use light meter to measure scene	An objective measure, but light meters measure a point source – not a whole scene. There is also the question of how such an objective measure is reflected in how humans interpret the scene. Experience elsewhere, notably from Bicycle Networks' light tests, is that objective measures are uncorrelated with subjective measures.

Given the difficulties in measuring changes in night-time rider demand *and* attributing that change to the treatment, a subjective rider-based assessment is recommended. Furthermore, given that video or photos of the treatment are unlikely to accurately portray how the human eye sees the treatment onsite trials are preferable.