Smarter Cambridge Transport

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To: Cambridgeshire County Council General Purposes Committee

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Subject: Review of Capita report and recommendations on guided busway defects

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Cambridgeshire Guided Busway Defects

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Introduction

Smarter Cambridge Transport is a voluntary community group seeking to advance integrated and sustainable transport for the Cambridge region. We have taken an interest in the Guided Busway because of the reported [2] need for repairs costing at least £36.5m. We noted that the author of that report, Capita, consider the busway design to be flawed, so that has been the starting point for our enquiry.

The *Executive Summary* and *Observations and Initial Questions* summarise our findings for a lay audience. The *Detailed Report* is aimed at a technical audience and covers the engineering aspects in greater detail.

Note that numbers in square brackets refer to documents listed at the end.

Disclaimers

This report does not constitute professional advice. Every effort has been made to ensure these notes are accurate. Any error or ambiguity brought to the authors' attention will be remedied without delay.

The authors have no particular expertise or experience in the design or construction of busways. They have brought to bear experience of engineering design in general, relating to structures, dynamics and vibration.

This paper draws only on information in the public domain, primarily the reports on the busway commissioned by the County Council from Capita, and direct observations of the overlying structure. The authors have not had the opportunity to examine the busway in detail (in particular the foundations) nor the original design documents.

Executive Summary

Smarter Cambridge Transport has reviewed the Capita reports on the Cambridgeshire Guided Busway, which catalogue and analyse various defects. The remedial action recommended in the November 2016 report involves rebuilding almost 50% of the shallow foundations. This will entail closing sections of the busway for extended periods, during which buses will have to be routed onto other roads. The lowest cost estimate, based on work being carried out proactively, is £36.5m. The cost rises to over £160m if repairs are carried out reactively.

However, the report states that ***this will not resolve all of the problems***. In light of this we have analysed the design, particularly regarding the foundations, the cracks in the concrete beams, and the poor ride quality evident along many sections of the track. We now believe these may be symptoms of fundamental flaws in the design and construction, which appear not to have been adequately examined to date.

Our report sets out some of these symptoms, and outlines possible theories to explain them. These have led us to believe there may be a high risk of future structural failure of the busway, possibly catastrophic. This would create additional, currently unquantified, liabilities for the County Council and further prolonged periods of closure of the Busway.

Risks

Failure by the council to obtain a complete understanding of the Busway defects and their causes exposes it to a **risk of considerable further expense and reputational damage** in the future, possibly within five years. In particular, the risk of a catastrophic failure of the busway, which could lead to deaths or serious injuries, must be quantified and agreed by councillors.

Capita is explicit in its reports that its investigations to date **are not comprehensive.** For instance, Capita has relied on just one theory to explain movement in the foundations (disturbance by tree roots), and has not proposed a theory to explain the extensive cracking found in most of the beams.

The reliability of cost estimates is unclear. We would expect all recommended courses of action to be presented with a range of costs and confidence levels to reflect uncertainties. What, for example is the probability that the proactive repair programme will cost £45-50m rather than £36.5m? Uncertainties are inescapable: for instance, it cannot be known yet how many components, including guideway beams, will need to be re-manufactured; or how long the recommended repairs will last; or whether foundations deemed OK now will fail in the future.

The economic and social impacts of temporary closure of the busway and cycleway ('maintenance track') also need to be examined.

Recommendation

The council needs a complete picture of the defects and design flaws in the busway; a comprehensive diagnosis of the causes, with all uncertainties spelt out in detail; and for, each of the proposed remedies, a range of costs along with an economic and social impact assessment. These are needed for four reasons:

1. To give the council the strongest negotiating hand with the original contractors in seeking a settlement for the repair bill.
2. To minimise taxpayers' current and future liabilities, and indirect social and economic costs of carrying out repairs.
3. To ensure that the repairs carried out are sufficient to ensure trouble-free operation until 2051, the end of the Guided Busway's design life.
4. To ensure that any design flaws in the existing busway are not carried over to a future guided busway, such as is contemplated by the Greater Cambridge City Deal.

We further recommend that the council consider and commission cost-benefit analyses of alternatives to repairing the busway, ranging from refining the design to converting the busway to a restricted-access road or a light rail line.

Observations and Initial Questions

We have summarised here some of the key issues that we believe need additional research beyond that already carried out by Capita. A theme running through these questions is the need to give greater consideration to dynamic effects, i.e. the interactions between moving buses and components of the busway.

1. The busway section around Histon has significant undulations. Capita has recommended only limited remedial works here.

   What assessment has been made of ride quality? Has this been correlated with proposed remedial works to ensure that all vertical and horizontal deviations have been accounted for?

2. Capita considered hedges and trees rather than geology to be the major contributory factors in the need to replace shallow foundations.

   What evidence is there that heave and subsidence are caused by tree roots alone?

3. NHBC (National House Building Council) construction standards for foundations typically apply to static buildings, not subject to high-impact dynamic loading.

   Are these proven and accepted standards for construction of a busway?

4. Some fifty per cent of the foundations Capita deems necessary to replace are between Swavesey and Longstanton. North of Swavesey, most of the foundations are piled, in accordance with the original design specification.

   Are the geological conditions that required piled foundations found elsewhere along the busway?

5. The foundations consist of compacted sand and gravel, contained by the surrounding soil, which partly consists of clay. Clay swells and contracts as it hydrates and dehydrates. This means that the sides of the soil 'box' containing the shallow foundation move in and out slightly over time. This could be what is allowing the foundations to move.

   To what extent has geology been examined as a possible explanation for subsidence and heave? Has the interaction between shallow foundations, the surrounding soils and changing water table been examined? What will be the impact of Northstowe, which is expected to lower the water table?

6. Many beams are cracking over much of their length, not just at the central V-notch. This is most notable between Histon New Road and Histon Station Road. Capita has recommended replacing only some of the foundations supporting affected beams.

What is causing the extensive cracking of beams?

7. Water ingress at cracks is creating opportunities for corrosion and frost damage. In particular, when the busway is gritted during the winter, if salt solution is reaching the reinforcing bars, it will be corroding them. These effects will be shortening the safe operating life of the beams.

   What analysis has been carried out on the integrity of beams that have cracks, in particular whether there is any sign of internal corrosion?

8. Rebuilding 821 foundations will entail lifting and relocating over 3,284 beams and connected spacers. Drilling the anchor pin holes will entail lifting all of the remaining beams.

   What proportion of beams and spacers does Capita expect to be re-usable after lifting? What is the uncertainty, and hence cost risk associated with the estimate being wrong?

9. Capita are recommending sealing cracks in the beams with bitumen.

   What research has been done into the effectiveness of bitumen filling of cracks in preserving the beams? How frequently will beams need to be inspected and re-treated? Has this been costed?

10. Bearings and shims have moved sideways which might suggest that beams are rolling or twisting slightly as buses run over them.

    How much analysis has there been of the movements, stresses and vibrations induced in the beams, bearings, shims, foundations and underlying geology by dynamic loading of the beams? Of particular concern are the effects of bus and guide wheels transferring loads from one beam to the next, especially at bends.

11. There have been two derailments of single-decker buses on the Cambridgeshire Busway, and one of a double-decker on the busway in Leigh (Greater Manchester).

    What analysis has been carried out to quantify the risk of derailment (e.g. owing to a beam up-stand breaking away under load, or a guide wheel riding up a damaged beam end)? Has the effect of derailment been modelled for a double-decker bus, in particular on a section where the centre of the guideway is open or in-filled with loose rubber, as shown in Fig 1 below?

12. The stresses placed on the up-stand of the outer guide rail on bends can be exceptionally high, especially at the joins between beams.

    Has this been analysed in detail?

13. In light of plans currently in development to build further stretches of guided busway, it would be prudent to re-evaluate the business case for the existing busway in light of cost overruns, identified defects and design flaws.

    What is now the safe operating life for the busway? What is the revised benefit-to-cost ratio for the Guided Busway, based on actual cost and ridership? (Ridership should not include journeys that do not reach the guided section, such as Peterborough to St Ives, but which are currently counted in reports on busway ridership.)

The *Detailed Report* that follows sets out in more detail the engineering issues that lie behind these observations, and poses further, more detailed questions.

Detailed Report

1. Background

On 7th October 2014, the General Purposes Committee of Cambridgeshire County Council received a report commissioned from Capita regarding 'Guideway Defects and Corrective Measures' on Cambridgeshire Guided Busway [1]. More recently, on 29th November 2016, the same committee received a second report dealing with further investigations into the same subject [2]. These notes deal principally with the second report, but make occasional reference to the earlier (2014) report.

Having reviewed the report in November 2016, the General Purposes Committee made a decision [3 – p4, Key Decision 11(c)]:

'Resolve to carry out works on the basis of Option 1 from this report to rectify all of the superstructure, foundation and drainage defects in accordance with the assessment of the Project Manager and the advice of the Council's expert technical advisers, subject to securing funds from Bam Nuttall in accordance with the defect provisions in the construction contract or alternative legal argument.'

At first reading, this implies that the Committee resolved to rectify all of the superstructure, foundation and drainage defects on the Busway. **This is not the case**: Option 1 covers only selected defects. The full report notes further defects and potential problems, which it specifically excludes from consideration. For example:

'It should be noted that remediating the foundations ... will not resolve the problems relating to the superstructure. ... the cracking over the central support is likely to increase.' [2 – p53, para 166]

and:

'An unknown element is the effect of any future foundation movement on the guideway ladders. It is possible that this will increase crack depths thereby reducing the stiffness…. We have not considered this aspect.' [2 – p20, para 67]

Repairing the defects covered by Option 1 has been estimated to cost £36.5m [4], and is predicted to put sections of the Busway out of commission for some 2½–3 years. During that time passengers will be faced with significant delays. This is likely to induce some to switch permanently to using private cars, adding to congestion in the city and on the A14.

After this huge additional investment and years of disruption, taxpayers will reasonably expect the Guided Busway to operate for rest of its design life, to 2051, without further unplanned costs and disruption. There is no guarantee of this: some of the components of the concrete guideway have extensive cracking; they will have been subjected to unplanned handling with the result that they may well be degraded and their lifetime shortened. The report extracts quoted above warn of potential future problems. Who will bear the costs of further repairs is not the taxpayer?

Secondly, we are aware that major infrastructure projects are being planned, potentially with an extension into Northstowe, and new routes from Cambourne and from Waterbeach into central Cambridge. If there are lessons which can be learned regarding design and project management, then they should be implemented ahead of the letting of further contracts either by Cambridgeshire County Council or by Greater Cambridge City Deal under delegated powers.

1.1 Construction

Buses on the Guided Busway run on concrete beams, 10m or 15m long. These are supported on foundations that are either piled or 'shallow' compacted material. Reports by consultants [1 & 2] have identified that 821 out of 1791 of the shallow foundations on the northern section (St Ives to Milton Road) are failing and require rebuilding.

Figure 1 shows a typical 15m 'ladder section', labelled with some of the key terms (in italics) used throughout this document. The depth of shallow foundations varies greatly. Figure 2 shows a shallow foundation being excavated during construction.

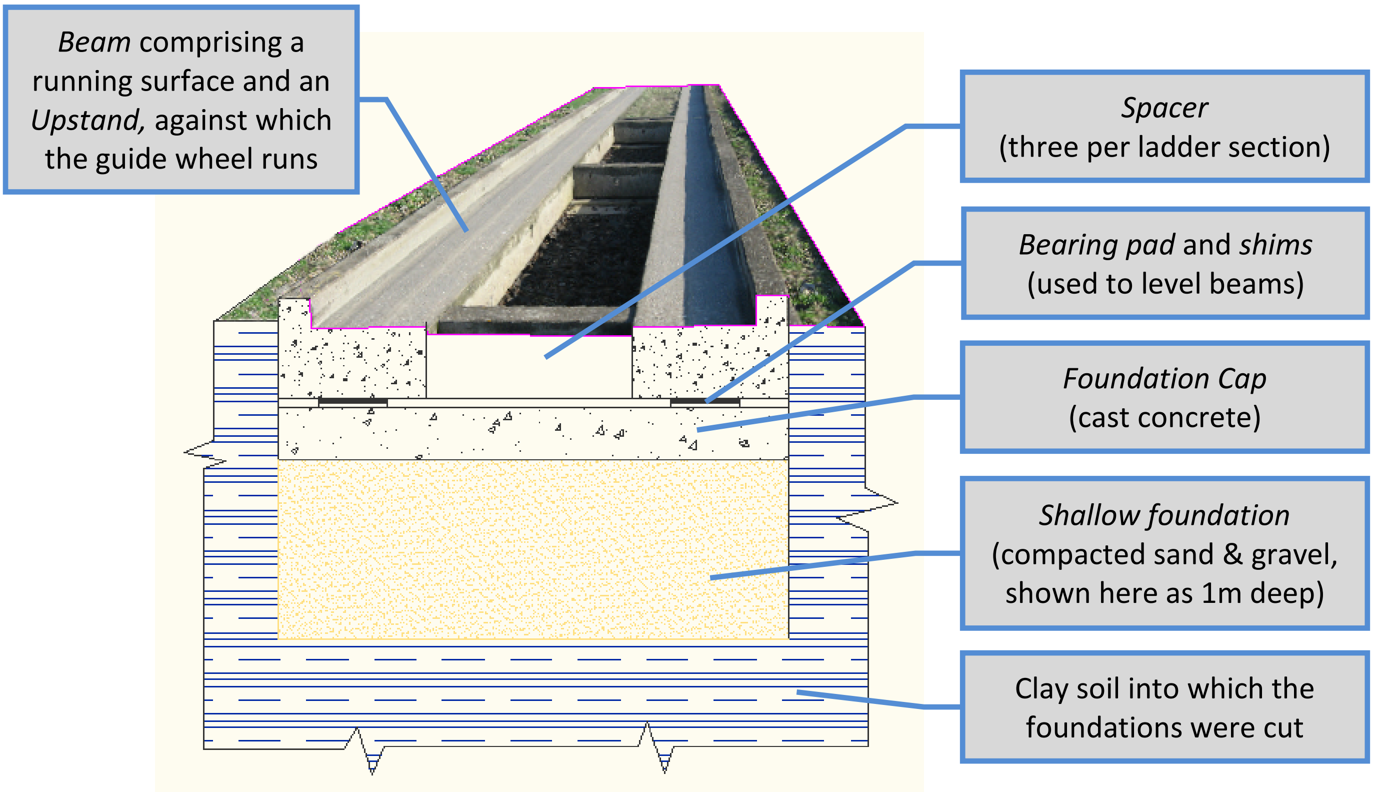

Figure 1: Cross-section of the busway showing a typical 15m 'ladder section' and one of three shallow foundations.

Figure 2: Shallow foundation [2-Fig 7]. 821 of these are to be re-excavated, deepened and re-instated

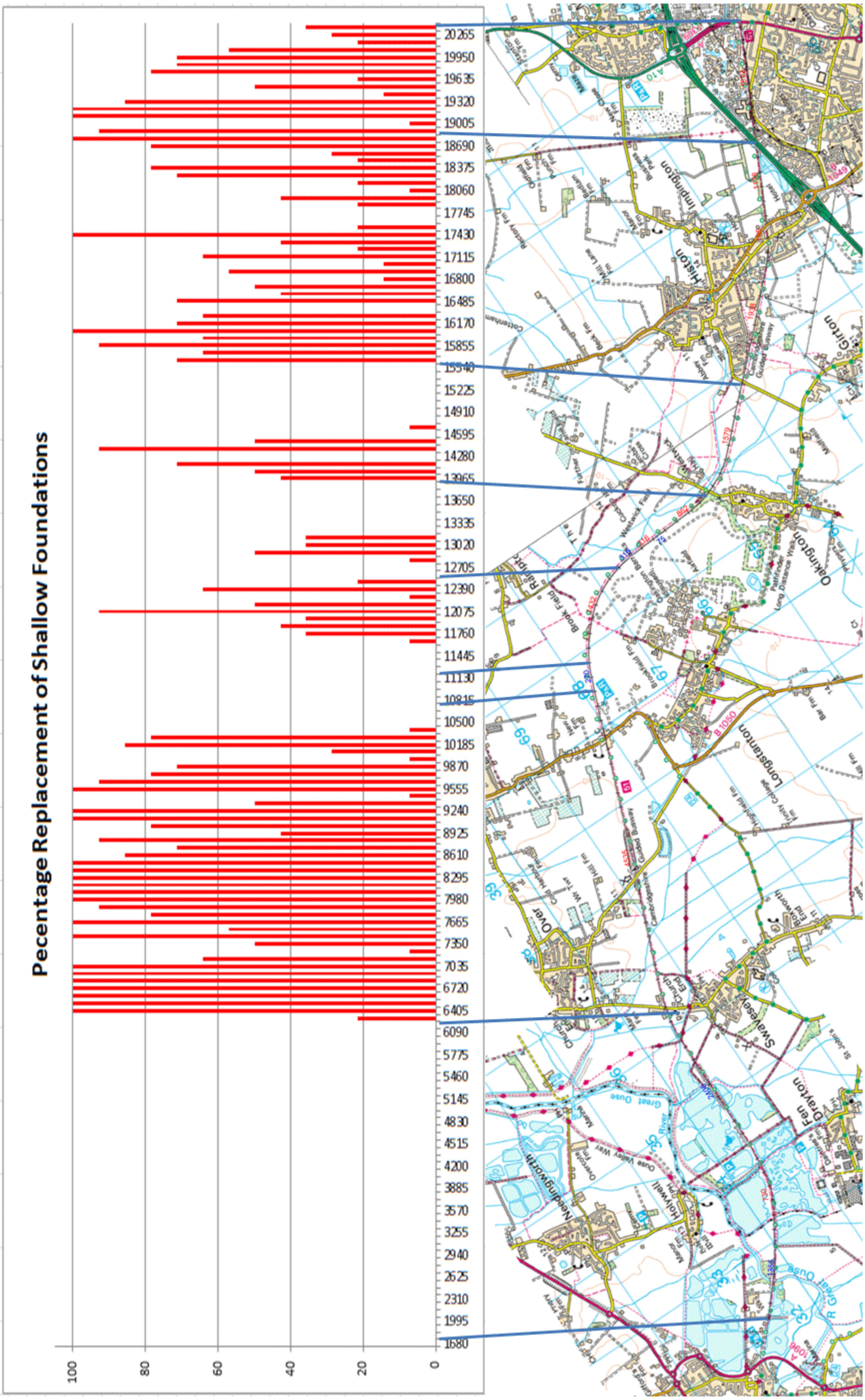

Figure 3: Location of foundations to be replaced. Piled foundations shown in blue, shallow foundations in red.

2. Guide rails and Spacers forming Ladder Sections

2.1 Guide rail cracking – number of cracks

We have walked the whole length of the Guided Busway from St Ives to Milton Road. Many of those beams contain cracks around the central support. Typically there is a crack emanating from the central V-notch. In some places, cracks extend into the running surface (Fig 4).

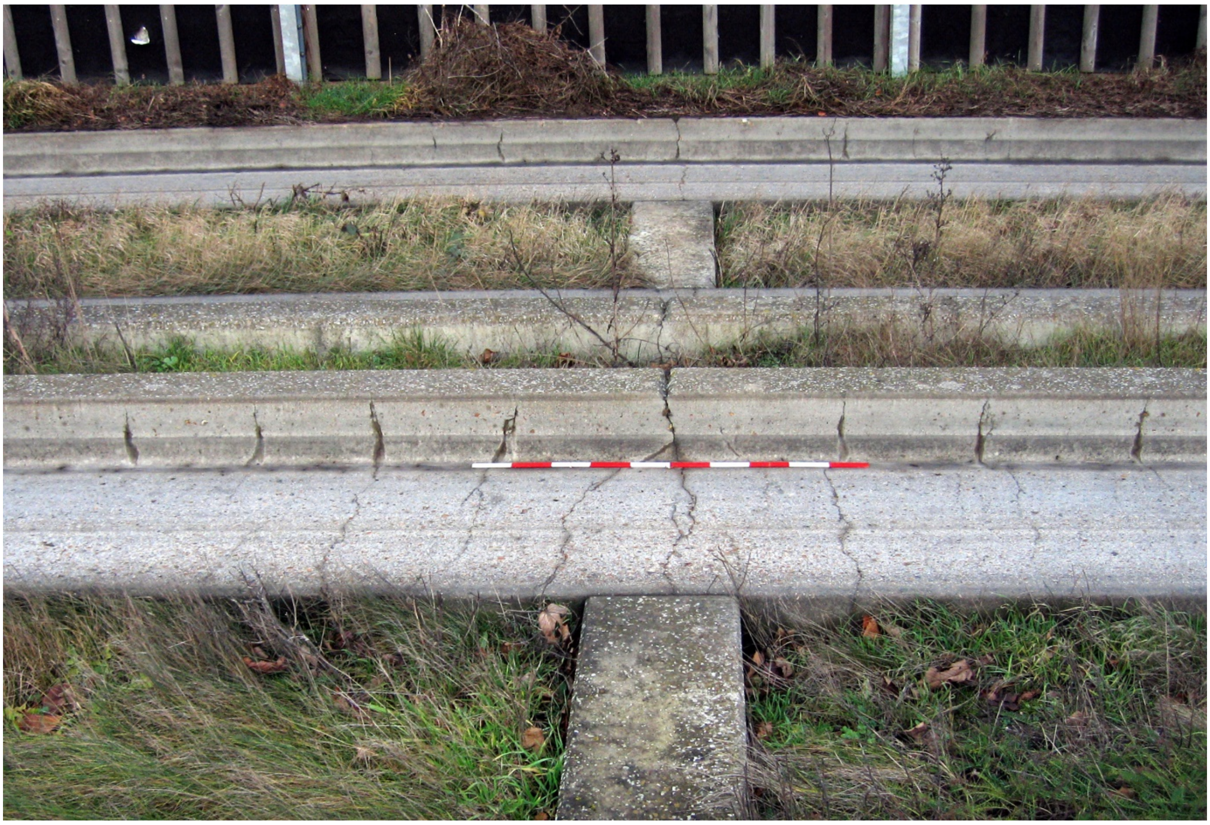

Figure 4: Centre of guide rail, showing V-notch and cracking. Scale bar: 1m.

Figure 4 shows part of the St Ives-bound guideway in the foreground, with the Cambridge-bound guideway behind. The length of beam in the foreground is approximately three metres. This pattern of cracking is typical of many in the Histon area.

Without treatment these cracks will worsen due to freeze-thaw and other factors. The report suggests injection with resin, and treatment with bitumen paint [2 – p41, para 142-3]. Given the extent of cracking shown above which has appeared within five years, it does not seem likely that this treatment will extend the life of the beams for a further thirty-five years. It is also noted that the amount of cracking is variable, but the degree of cracking at any location along the route is generally mimicked in all four beams.

The Capita report indicates that various foundation points have been subjected to heave and have risen, whilst others have shrunk. The report does not provide an explanation for what appears to be a highly unusual phenomenon: an alternating geological pattern of heave and shrinkage that coincides with the 15m span of the beams.

The report suggests that the beams will be lifted and set aside whilst the foundations are dealt with [2 – p39, para 137; p40, para 140]. From the degree of cracking already present, and the close dimensional tolerance required of the guideway [5 – p8, para 4.3, 4.4], it is possible that some beams may not be reusable.

Question 2.1.1
Is it the case that the cracking shown in the beams in Figure 4 is caused by heave in the centre of the beam or is there some other explanation?

Question 2.1.2
How many of the existing concrete beams are expected to be reusable after being lifted? Assuming no spare beams are presently held by Cambridgeshire County Council, what is the cost of casting and transporting new beams to site?

2.2 Guide rail cracking – size and nature of the cracks

The report states:

' ... the cracking over the central support is likely to increase (we have calculated this to be around 0.3mm) ... ' [2 – p53, para 166]

The timescale of the increase of 0.3mm quoted in the report is unclear, but presumably refers to the remaining life of the beam – approximately 35 years.

Figure 5 shows a crack in one beam. At the top of the upstand, adjacent to the V-notch, the crack was measured and found to be 0.6mm wide. This gap in this beam has occurred over five years.

Figure 5: Crack originating at V-notch. Measured photogrammetrically as 0.6mm.

The report suggests treatment with resin and bitumen paint [2 – p41, para 142-3].

Question 2.2.1

When the report states that gaps are calculated to increase by 0.3mm:

a) What factors were considered as being causal?

b) Is this typical or a maximum?

c) Is the calculation done for the entire future life of the guideway (approx 35 years)?

2.3 Guide rail assembly

The ladder beams are assembled by bolting through onto spacer blocks. [2 – p6, para 10].

With this type of assembly in mechanical engineering, there would be great concern to ensure the end faces of the spacers were flat and parallel, normally achieved by specifying the tolerance of the parallel faces, by surface grinding if necessary, or by introducing compressible gasket or shim material between the elements to take up any out of squareness. This has apparently not been done in most of the ladder assemblies. Initially this is likely to result in significant point stresses in the structure where concrete abuts concrete; subsequently the lack of resilience means that bolts are likely to work loose by thermal and vibration effects.

It is indeed clear that the fixings are not holding the spacers securely: some have rotated. Examples are shown in the report [2 – p35, para 123 & Fig 18]. The spacers have rotated because the clamping force on their ends is not sufficient to hold them in their correct position. The spacers move independently with respect to the two beams, hence in the long term the left- and right-hand beams can move relative to each other.

Question 2.3.1

To what tolerance are the spacers manufactured, particularly with regard to the flatness and parallelism of the end faces, and have any tests been undertaken to confirm that a rebuilt structure will maintain the beams parallel within the original tolerances specified for the guideway?

3. Foundations

It is reported that the foundation design has been based upon NHBC guidelines at the time, but with modifications.

The criteria for foundation design is given as NHBC guidelines where no trees are present (referred to here as x1) or doubling of the depth where trees are close by (referred to here as x2). Apparently foundation depth of x1.5 has been used throughout.

This would imply that some foundations are over-designed. Where *no* trees are present, the foundations should have been x1, but were built at x1.5, that is 50% over-engineered.

The report does not provide a correlation of position of failed foundations with the position of trees. However, it does indicate that over eight hundred foundations require rebuilding. The implication is that foundations at x1.5 are not adequate, but rebuilding to x2 will solve all of the problems.

Whilst comments are made regarding presence of trees, it seems that no account has been taken of any future change in the water table due to building. It is noted that the new town of Northstowe is adjacent to the Guided Busway. Furthermore, the County's *Guidance for Developers* states 'the CGB encourages soft landscaping in the vicinity of the Corridor and CGB land' [6 – p10, para 9.3].

It seems that foundations are to be redesigned according to what trees are present at the moment, with no consideration for what may be planted and grow up over the next thirty-five years. The *Guidance* does not rule out planting trees adjacent to the Busway (it only identifies certain tree species to avoid).

The size of the 'shallow' foundations are noted in the 2014 report [1 – p7, Fig 7], reproduced above (Fig 2). It would appear from the photograph that the volume of material present in such a foundation would require several journeys by heavy vehicles to remove it. The report notes that 821 of these foundations are to be excavated, deepened and re-established, using compacted Class 6N fill. It is unclear whether all of the excavated material will be removed from site and fresh material brought to the site, or whether some of the original material may be re-usable.

Consequently, there appears to be no indication of the number of vehicle movements which will be required to accomplish this or any of the other tasks. Nor is there any indication of the disruption to local villages caused by heavy vehicle movements, or any other indication of the environmental impact on the locality.

Furthermore, the foundation pit is formed in clay. The clay has been compacted by many years of supporting the track bed of an old railway line. It is suggested that this clay will be relatively impervious. Surface water draining into the foundation pit will have little opportunity to escape. As a result, the pit will remain filled with a slurry of loose fill and water. When vehicles load the foundation cap, the slurry will be pumped outwards, potentially causing erosion of the sides of the pit, and subsequent partial collapse.

Question 3.1

Has any study been done to confirm the correlation between failed foundations and adjacency of trees or is this supposition?

Question 3.2

Have any predictions been made for changes in water table caused by proposed substantial building work in the area – for example the new town of Northstowe – or for tree planting by developers?

Question 3.3

How many heavy vehicle movements will be required to dispose of material excavated from the foundations, and how many more will be required to bring fresh material onto the site? Has any consideration been given to the overall environmental impact of carrying out the remedial work proposed in the 2016 report [2]? If so, could a copy of the assessment be provided?

Question 3.4

Has consideration been given to the consequences of foundation pits filling with surface run-off? If so, what is considered to be the action of the resultant slurry under dynamic conditions?

4. Dynamic Loading on the Guideway and its Effects

Throughout the design notes and reports, it seems that consideration is given to static loading. The 'probable mechanism' for how the bearings and shims displace is considered to be expansion and contraction due to thermal effects [2 – p30, para 105 and Appendix F]. Whilst this is clearly a consideration, a thermal cycle will typically occur once per day, and then only over a limited range.

It is to be expected that buses running on the guideway will introduce dynamic stresses and potentially movement of the structure. This section considers some of these effects.

On average about forty vehicles – that is eighty axles – per day pass each point on the guideway, so subjecting it to eighty cycles of vibration as the wheels pass any one point. Vibration is either induced by such things as the engine or the tread pattern of the tyres, but particularly when vehicles cross joints between beams.

Vehicles passing over the joints make a noise in much the same way as a train passing over rail joints. But, in some sections, there is also a rhythmic 'clunk' as the vehicles pass along the guideway. The noise is reminiscent of a loose paving slab on a pavement. This suggests that the beams may be moving as the wheels load the beams. It is not possible to confirm this without a fuller investigation, and this only applies at some joints, so the investigation points would have to be carefully selected.

Drawings for new bearings and shims indicate that they should be 400 x 300mm (width x length), apparently on the centre line of the beam [2 – p133, Drawing 1 sheet 1]. Photographs of the guideway as it was being built indicate this is to be a repeat of the original build [2 – p7, Fig 2].

4.1 Displacement of bearings and shims

Figure 6 indicates the loading from front (single) (Fig 6a) and rear (double) wheels (Fig 6b). It will be seen that the bearings directly support the load on the front wheels. However the rear wheels put a load inside the bearing and shim stack. The inner edges of the beams roll away from the spacers; the through bolts stretch and allow the beams to push the beams outward. Friction between the foundation block, bearing, shims and beam is not sufficient to constrain the movement.

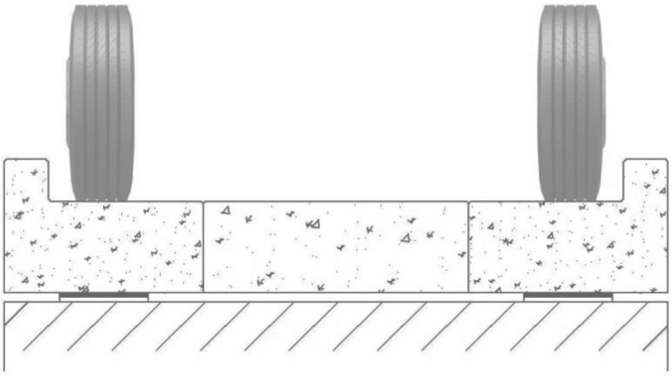

Figure 6a: Front wheels load the beams above the bearing points.

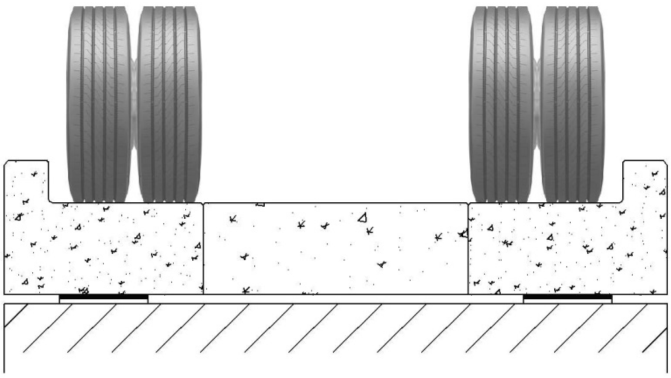

Figure 6b: Rear wheels create an offset load on the bearing stack, causing the beams to roll. This puts stress on the beams, spacers and fixings, and tends to force the stack outwards as shown below.

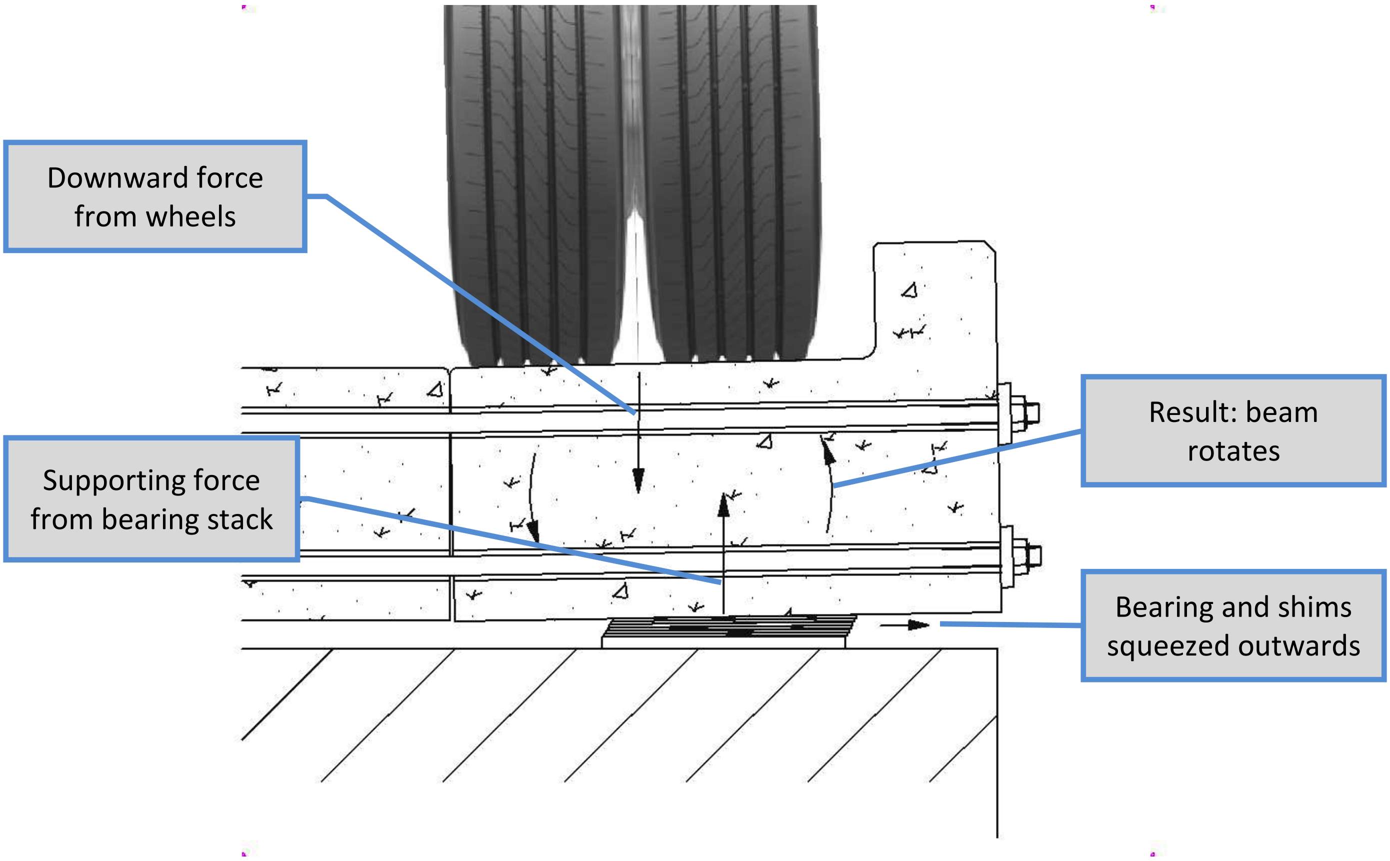

Figure 6c: Detail, showing turning moment created by loaded wheels. The bottom of the beam rolls outward. The beam is partly constrained by the retaining bolts, but the bolts stretch and allow the stack to slide.

Fig 7 Fractured centre spacer. The spacer has pitched forward. The top of the beams have apparently rolled inward and pinched the spacer, as indicated in Fig 2c, above, resulting in fractures at both ends.

Question 4.1

It appears that vehicles with twin wheels (typical on the rear axle) are likely to cause the beams to roll inward as the vehicle passes along the guideway. In the suggested

repairs to the Busway, has any account been taken of the possibility that the bearing area is not large enough to support the beams, and of the potential degradation which this may continue to cause?

4.2 Uneven settlement of foundations

The reports focus upon the effects of tree roots upon the foundations. We can find no indication of a study of the effects of vibration.

As vehicles leave one guideway beam and move onto the next, vibrations will be induced through the superstructure and into the foundations, and hence would appear relevant.

A typical bridge structure would have a deck which is relatively massive, and comprising some aggregate. As a result, vibrations are adsorbed without being imparted to the foundations. There is little adsorption in the structure of the guideway, and much of the vibration energy will be carried through to the foundations.

The end of the beams is at right angles to the direction of travel. As a result tyres impact come off one beam onto the next suddenly, and generate a shock wave with a sharp rising edge. Had the beam ends been angled, the weight of the vehicles would have been transferred from beam to beam with less percussion, and there would have been more opportunity for energy to be dissipated within the structure.

Whilst each shock wave is relatively small, the cumulative effect of some eighty axles per day (28,000 per year) is likely to have a distinct effect upon every element of the structure. Along several sections of the Busway when running at speed a poor ride quality is noticeable – the bus is lifted sharply and on a regular basis as though hopping. These uplifts apparently occur at 15 m intervals and at the centre point of the beam. This is consistent with the centre foundation being higher than those at the ends which are under the joints.

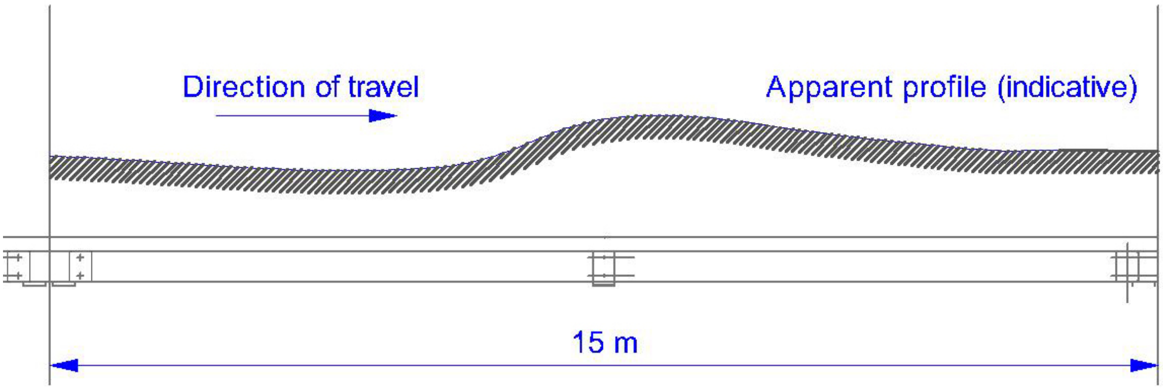

Figure 8: Indicative profile of the ride for extended sections of the Busway. The observed motion of the vehicle will differ from

the profile of the beam, having been modified by the vehicle suspension.

We note comments regarding heave, particularly in relation to shrinkable clay and trees [2 – p58 para 187]. However, the 'hopping' occurs over extended lengths of the Busway. The geology is varied, but the phenomenon is apparent over significant stretches of the route, and we suggest that a mechanism other than shrinkage and heave may be present.

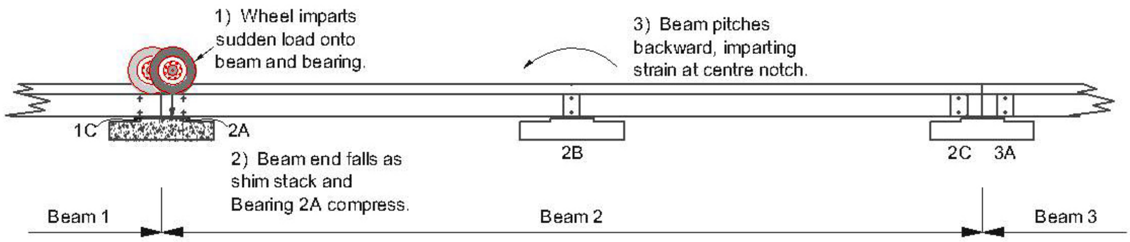

Figure 9: Action and reaction of a beam as it is receives an impact from a loaded wheel.

With an 18 tonne dual axle bus approximately 3.5t is taken on each of the front wheels. With the wheel at the end of Beam 1, the load on 1C is a total of 7.3t (beam with bus), and the load on 2A is 3.8t (beam alone).

When the wheel crosses onto Beam 2, the situation is reversed, and load on the bearing 2A suddenly increases from 3.8t to 7.3t. The shims and bearing will be flattened and compressed; the beam end receives a sharp blow (mitigated by the vehicle tyres) and will move downwards.

Bearing 2B is already loaded by half of the weight of the beam. It takes little of the additional weight of the bus, so initially the effect will be that the distant end of the beam rises, offloading 2C. The rotational torque is imparted by tension in the beam above the centre, concentrated around the V-notch.

We suggest that a significant reason for cracking is cyclical percussive loading as bus wheels hit the start of each beam.

Bearing 2A will take an impact load from the wheel. This will be imparted to the foundation through the shims and bearing. A small movement in the foundation slab will be imparted to the underlying soil. By the time the rear axle arrives at this point the load from the front will be almost over the centre bearing, and Bearing 2A will have been substantially offloaded. The second axle of the bus imparts a percussive load of approximately 11t with even greater effect than the first.

It is not the purpose of these notes to quantify the movement. However, the effect is potentially cumulative. With forty vehicles per day, even a movement in the foundation block of 0.2 micron per axle will result in a total of approximately 6 mm per annum. This is small compared to some of the changes reported in the foundations.

We suggest that a significant reason for differential settlement of the foundations is because of percussive loading by wheels as they impact the start of the beam. The loading on the centre foundation is much smoother by comparison.

Question 4.2.1

Has any consideration been given to the cause of the poor ride quality along significant sections of the Busway, and in particular whether variation in height of the foundations may be due to percussive loading at the joints of the beams?

Where next?

In view of the doubts raised by Capita over the design integrity of the Busway, the concerns we have raised here, and the huge cost and disruption that is now inevitable, should the council not consider more options than just repairing the busway?

We note the suggestion that Construction Trials be considered [2 – p56, para 175] to test the practicality of construction methods. This seems entirely appropriate. In addition, we would suggest that some of the beams which have suffered degradation should be removed from service and subject to accelerated life tests. With an appropriate test rig subjecting the beams to an impact loading at, say 30 second intervals, the beam would be tested at approximately 35 times its working rate. Thus within a year there would be confirmation that the Busway would indeed have a total working life of forty years.

If these tests determine that the construction design needs to be modified to extend the working life, then that should be considered as another option. That would also provide an opportunity to make any necessary modifications to the design to accommodate other vehicles the council may want to permit onto the busway in future: maybe triple-axle buses (which are likely to accelerate wear in the current busway implementation), articulated ('bendy') buses, cargo vehicles, and driverless vehicles of a range of sizes.

Whilst the wheel-on-kerb guidance may appear reassuring, there are reasons to doubt this, for example:

A. Several accidents have occurred on busways in Cambridgeshire and elsewhere, most of which have been attributed to driver error.
B. Vehicles have to slow down even at light-controlled intersections in order to re-engage safely with the guideway.
C. Buses cannot overtake an obstruction or reverse along the guideway.
D. Vehicle breakdowns cause major delays and recovery is slow.

Guidance technology is making considerable advances: optical guidance combines precision with the flexibility of manual override; and collision avoidance technology can already monitor and respond to traffic conditions one hundred metres ahead on a crowded motorway.

We should be asking: What can we learn from the experience of building and running the existing busway? What design and technology is most appropriate for the twenty-first century?

These questions are especially pertinent in light of the fact that the County Council and

City Deal are considering building busways to link Cambourne and Waterbeach to Cambridge.

We believe that a number of options should be considered and subjected to cost-benefit analysis. At a minimum these should include:

1. Repair the busway to meet the original construction specifications.
2. Modify design elements and rebuild in order to extend the busway life and to accommodate vehicles that we may want to run on it in future.
3. Replace the busway with a kerbed, tarmac road (as in Runcorn).
4. Replace the busway with a light rail line.

Conclusions

The report published by Capita in November 2016 indicates that the design of Cambridgeshire Guided Busway is deficient in several respects. The investigations upon which the report is based were conducted within five years of the Busway going into service in August 2011.

We believe there are significant grounds for concern about the integrity of the busway in its present form. There is a lack of data in the public domain to reassure us.

Although some of the issues of the last five years may be put down to initial settlement, there is little to indicate that movement has stopped. The geology is varied along the route of the Busway, and will continue to change as development continues close by. Establishing secure foundations has proved difficult in the past, and Capita confirm that even rebuilding with revised foundation design carries no guarantees.

It appears that no account has been taken of the root cause of degradation of the beams. Lifting them to replace the foundations is likely to further degrade the superstructure. Problems have developed in the beams in the past five years. We are not convinced that patching them with resin and bitumen paint is likely to provide the 40 year lifetime which is the basis for the original costing of the busway.

In addition, there is no indication that the effects of on-going building work, for example at Northstowe, have been considered.

The work on this occasion should be a definite fix, rather than something which is repeated every few years. The monetary cost of £36.5m plus legal fees plus potential compensation to the operators may be recoverable on this occasion; if it is, it will likely be 'a full and final settlement'. Local taxpayers will have to foot any future bill and suffer the disruption and loss of amenity while further repairs are carried out. Therefore, any remedial action must resolve all design issues *now*.

We submit that questions posed in this document should be fully addressed and that taxpayers deserve comprehensive answers, supported by robust data. There is only one opportunity to fully resolve these issues whilst maintaining any likelihood of recovering losses from the original contractor.

It may be that pursuing litigation in order to repair and rebuild the busway to the current design specification is not the best option for the County Council and the residents it represents. Other options should be examined and compared.

The whole concept of a kerb-guided column-and-beam busway should be reviewed, particularly in the light of advancing guidance technology.

References

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This report refers (para 1.2) to a Capita Report dated 6 October 2016. It is believed that this is the same report which was put into the public domain as Reference 1, above.

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