Docklands Light Railway's Noise and Vibration Policy 1989

by

Bryan Fitzgerald BTech CEng MICE MIHT

DLR Noise and Vibration Policy

Docklands Light Railway (DLR) is a light rail rapid passenger transit system that serves the needs of residents and businesses within the London Docklands regeneration zone. The network threads its way through densely populated areas of east London, often very close to residential façades, so noise and vibration generated by passing trains has been a priority issue for the operator.

The Noise Policy was drawn up by London Regional Transport (LRT) in March 1989 and laid before the House of Lords Select Committee during the process to secure parliamentary powers for construction of the Beckton Extension of DLR. The Noise Policy, which is still current policy, is a statement of LRT's intentions for the control of noise and vibration caused by the operation of the DLR which would be carried out so far as is compatible with the duty imposed on LRT by the London Regional Transport Act 1984.

The Noise Policy went on to state that in locations where the target levels were exceeded on the existing railway, LRT (or more recently DLR) was to use best practicable means to minimise the levels of exterior noise. In this context, 'practicable' is reasonably practicable having regard among other things to local conditions and circumstances, to the current state of technical knowledge and to financial implications. Such means may include physical works and maintenance procedures which could be carried out at reasonable cost and so far as is compatible with DLR's statutory duties as regards efficiency, economy and safety of operation.

The Noise Policy sets down systemwide procedures for monitoring and maintaining the control of noise. A list of representative noise monitoring locations is agreed with the local authorities concerned. This was done following implementation of the Noise Policy and the list has subsequently been reviewed from time to time. The local authorities concerned these days are the London Boroughs of Tower Hamlets, Newham, Greenwich and Lewisham.

During the baseline measurement exercise, now carried out annually, in the event that the maximum noise level of any vehicle is found to be 5dB(A) or 5dB(C) or more greater than the mean measurement of all vehicles measured on any previous occasion, the wheels of that vehicle are to be scheduled for re-turning as soon as reasonably practicable. This has become known as the wheel turning criterion.

In the event that in any location the mean of the noise levels of all the vehicles measured subsequent to the relevant baseline measurement on any one track is found to be 5dB(A) or 5dB(C) or more greater than the mean measured on any previous occasion then the track is to be reground as soon as reasonably practicable. This has become known as the rail grinding criterion.

Upon reasonable request by the local authority, vibration measurements are carried out at agreed residential locations. In the event that the measured levels are in excess of those specified in BS 6472:1984, DLR is to use best practicable means to reduce vibration to below the specified levels.

The concluding section of the Noise Policy relates to noise insulation measures. However, this applies to what is termed the 'Beckton extension service' – the railway operating on the length of route running from Bank or Tower Gateway to Beckton. Also, the obligation on DLR to provide noise insulation at eligible premises was timed to expire 18 months after the opening of the Beckton Extension service. As the Beckton Extension opened in 1994, the expiry date has now passed.

It was the intention of LRT that noise from the traffic patterns on the then existing railway, before the opening of any extensions, should not exceed given free field L_{eq} noise levels adjacent to existing buildings. These target free field L_{eq} noise levels are shown in Table 1 over the page.

	Period		Free field L_{eq} (dB(A))
Residential areas	Day	07:00 - 19:00	60
	Evening	19:00 - 23:00	55
	Night	23:00 - 07:00	50
Commercial areas	Day	07:00 - 19:00	60
Schools	Day	07:00 - 19:00	60

Table 1. Noise Policy target levels

Noise levels would be measured one metre in front of the relevant building façade and a reduction of 3 dB(A) would be made to the measured levels to take account of façade reflections.

Traffic generated by both the City and Beckton Extensions would have the effect of increasing the L_{eq} values on the existing railway. Provided the condition of both the rolling stock and the track did not significantly deteriorate, it was expected that this increase in service level and frequency would increase the target L_{eq} values by up to 5 dB(A) above those in Table 1. The target levels, therefore, in Table 1 would all be increased by 5 dB(A) for the lengths of the existing railway affected by the extensions.

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In the event that measured levels of vibration are in excess of those specified in BS 6472:1984, DLR is to use best practicable means to reduce vibration to below the specified levels.

If noise levels produced by the Beckton Extension service measured during the first year after the opening date – or predicted by DLR to occur within 15 years thereafter – exceeded 65dB(A) 24hr L_{eq} measured at one metre from the façade of any residential premises, and if a qualifying claimant within the specified period requested DLR to provide secondary glazing and sound attenuating ventilation, DLR was to install the same to the standard required by the Noise Insulation Regulations 1975. DLR would carry out noise measurements during the first year of service, or make predictions for the ensuing 15 years, in consultation with the relevant local authorities and DLR would make any offer of secondary glazing and sound attenuation to a qualifying claimant within 18 months of the opening date.

North route noise barriers

The route of the railway towards Stratford runs through an area of residential properties mixed with light industry. The site designated for noise reduction measures is bordered on one side by a local authority housing estate and on the other by Spratt's Warehouse, a factory refurbished into studio apartments. The housing estate comprises a mix of low rise terraced housing and high rise flats whilst the Spratt's Warehouse complex is made up of four and five storey brick warehouse buildings. The railway runs at grade through the site on ballasted track with trains reaching speeds of between 60 and 65 km/h as they cross Limehouse Cut canal at one end of the site. On both sides dwellings are situated very close to the railway and this proved the primary reason for high levels of noise; and not just from direct airborne noise from passing trains but also from low frequency rumble as they crossed the canal bridge. Background noise in this area is generally low. Noise measurement showed that the greatest problem occurred at Spratt's Warehouse, situated just 10 m from the track with the maximum exceedance above target noise level of 11 dB(A) occurring during the night and predicted to increase to 14 dB(A) in the future.

A range of options for reducing noise was examined and the selected one was to erect high noise absorbent barriers on both sides of the track over a length of 200 m with barrier heights of up to 2.5 m on the housing estate side and 3.5 m on the Spratt's Warehouse side. Noise level contours across the building façades had been calculated for different height barriers and the requisite heights were then confirmed once the contour values were shown to lie below noise policy targets.

Timber noise absorbent barrier panels were erected, supported by steel I-section posts at 4 m centres. The posts were founded in cast in situ concrete piles to suit the prevailing poor ground conditions and to control lateral deflection of the noise barrier. To reduce the overall height of the barrier in front of Spratt's Warehouse, the top metre was canted at 45 degrees towards the railway but maintaining a safe distance from the vehicle kinematic envelope. The kinematic envelope defines the extent of the trains lateral movement when in motion. The noise barriers are fully demountable for maintenance purposes and constructed so that the panels can be lifted out and the posts unbolted and laid down.

Her Majesty's Railway Inspectorate (HMRI) required a safe walking route to be maintained on one side of the railway and this is accommodated beneath the canted section of the taller barrier in front of Spratt's Warehouse. The question of aesthetics and the visual impact of a linear noise barrier was raised during the planning application stage with the provision of landscaping being a condition of the Planning Consent. The communities on both sides of the railway now enjoy an added amenity.

Upon completion of construction, noise measurements were taken which confirmed a maximum reduction in overall noise level in excess of 16 dB(A) which in turn has resulted in levels of noise received at adjacent buildings being generally well below the stated target figures.

Limehouse Cut Bridge

Limehouse Cut Bridge spans 30 m across the canal and consists of two steel plate girders supporting steel cross beams with shear connectors for composite action with the reinforced concrete bridge deck. Across the bridge the rails are fixed directly to concrete track slab units laid on the bridge deck. Further measurements taken on the bridge yielded noise and vibration spectra exhibiting broad peaks between 50 and 100 Hz, with a clearly defined peak in the region of 80 Hz. The overall noise level contained an element of airborne noise as well as noise originating from structure borne vibration but the extent of airborne noise could not be quantified until after appraisal of the works carried out to mitigate the structure borne element.

A number of solutions to reduce noise from the bridge were considered but the favoured option was to examine ways of acoustically isolating vibration in the rails (set up whenever a train passed over) thereby preventing it from being transmitted into the bridge and being re-radiated to the surroundings as noise. Studies defined the optimum dynamic stiffness and loss factor parameters for elastomeric baseplate grout pads enabling precise specification of the material grade to be made: in this case a pourable polyurethane grout was chosen not only because it possessed the required stiffness characteristics but also as it assisted with overcoming major dimensional variations in track slab surface level.

Airborne noise from trains on the bridge was reduced by the use of a low level noise barrier. The comparatively low height of one metre could be achieved as the panels were located close in to the train kinematic envelope and below vehicle floor level.

Measurements made adjacent to Limehouse Cut Bridge showed that the effect of track isolation on the bridge was to shift the peak vibration velocity value down to the 40 Hz frequency band and produce a significant reduction in re-radiated noise from 50 Hz upwards. The peak in vibration velocity at 40 Hz was not of a significant level in relation to the remainder of the vibration spectrum and there was a corresponding reduction of 5 dB(A) in terms of overall noise.

West route noise barriers

The second of the two sites influenced by railway noise exceeding noise policy target levels is very different from the north route one. The line between Limehouse and Westferry stations on the west route of the railway runs on the previously disused Limehouse brick arch viaduct which was built in 1839 and which in part is a Grade II listed structure of special architectural and historical interest. The tracks are laid on ballast. The neighbourhood is characteristically urban residential with a church and school close by and small businesses located within a number of the arches. The dwellings are nearly all grouped in medium rise blocks of flats of either five or six storeys. Some of these dwellings are in close proximity to the railway by as little as 5 m in one instance. Although not situated far from Westferry station, train speeds quickly reach 65 km/h.

As before, measurements of train noise were obtained and computer generated plots of noise contours were produced for all of the affected buildings. The maximum future period L_{eq} noise level was predicted to reach over 73 dB(A) which corresponded to a level in excess of 6 dB(A) above target level. Noise control measures, therefore, were required alongside these properties.

The number of mitigation options was basically limited due to restricted space on the viaduct and pointed to the use of acoustic barriers. Various barrier insertion loss plots were superimposed on to the noise contours for a range of barrier heights and the optimum values obtained dictated a 1.8 m high barrier rising to 2.5 m alongside the closest buildings. A 260 m length of track was treated but with discontinuous lengths of noise barrier which fully met the specified acoustic requirements.

An architect was commissioned to assist with the issue of aesthetics on this scheme, bearing in mind the need for Listed Building Consent as well as Planning Consent and the visual impact on the neighbourhood. The proposed scheme, which was acceptable to all parties, comprised a high-tech looking, late twentieth century extension to the mid nineteenth century viaduct. This was expressed in the use of metal cladding material and a colour scheme in shades of grey. Dialogue was maintained with the UK Government's English Heritage Department who expressed satisfaction with the architectural proposals and Listed Building Consent was subsequently given.

The structural form of the brick arch viaduct precluded the use of cantilever supports at track formation level. The solution, therefore, was to employ a series of steel portal frames spanning the railway tracks at 5 m centres and supporting metal-clad noise absorbent panels. Consequently, foundations were confined to precast concrete pads dowelled into the top of the viaduct. The top 700 mm of acoustic panel could be canted towards the trains within the overall column width.

Like the north route barriers, these barriers were designed to be fully demountable. Existing walking route widths alongside the tracks were already considerably restricted and it was HMRI's requirement to maintain these clearances. The solution was to erect the portal columns within the width above the brick parapet and provide a continuous level walkway platform across the offset column feet to avoid any trip hazards to staff trackside and passengers evacuated from trains.

Post-installation noise measurements made on site enabled period L_{eq} values and new noise contour plots to be prepared which showed resulting noise levels to be significantly lower than the target values. In terms of period L_{eq}, there was a general level of performance equal to an overall noise reduction of 11 dB(A). The barriers were so successful at reducing the overall noise level from passing trains that some residents were beginning to be conscious of individual impulse noises, such as worn rail joints, which had previously been masked.

Research and development

It was concluded, however, that concentrating effort on one site at a time was not the most cost effective way forward and so a broader strategy was formulated to address the noise problem across the whole railway network. DLR embarked on a programme of research and development exploring more novel noise control measures. The programme commenced with a noise source identification exercise which concluded that vehicle rolling noise was the dominant noise source on straight line ballasted track and at moderate speeds; and that the major noise contributor was the wheel rather than the rail. Other more minor contributors included compressor noise (particularly when idling at stations) and contact noise between the traction current pick-up shoes and the third rail at low speeds. The wheel/rail rolling noise was exacerbated by the impulse noise from wheel flats when they arose. These findings effectively pinpointed the source of DLR's train noise near rail height.

Low level noise barriers

It is acknowledged that the degree of screening provided by a noise barrier depends on the relative positions of the noise source and the receiving point. Consider a straight line between the noise source (assumed to be the rail head in this case) with the top of the barrier and extrapolate it beyond the barrier into the noise reception zone, ie equivalent to the limit of the line of sight towards the source point. The area behind the barrier and beneath the line of sight is termed the shadow zone. In general, a receiving point must be located within the shadow zone to gain the greatest benefit from the noise attenuation properties of the barrier.

DLR began to investigate the merits of noise barriers of reduced height with a view to developing a less expensive but technically effective barrier system which was quick and easy to install, not visually intrusive nor a hindrance to track maintenance. The principle was to provide a noise barrier of sufficient height to screen just the train wheels and bogies, ie the area around the noise source, and positioned close in to the train in order to maximise the shadow zone to that afforded by a conventional high barrier.

A prototype low level noise barrier was developed for use on ballasted sections of track with panels mounted on steel posts cantilevered off the ends of rail sleepers. This enabled the barrier to be maintained on a fixed line parallel to the track whilst maintaining a safe distance from the kinematic envelope of the train. A programme of full scale site trials was undertaken at one location on the railway to assess the acoustic performance of various types of panel construction, to measure the levels of vibration being transmitted into the posts and panels, to validate predicted levels of wayside noise reduction and to appraise the barrier system for ease of installation. Types of panel construction investigated included timber reflective, timber absorptive, metal absorptive and timber faced with a proprietary wood fibre cement based noise absorption material.

Noise measurements were made with a CEL-593 sound level analyser at various distances and heights within the shadow zone behind the barriers and during train pass-by events. All of the noise absorptive type panels provided levels of insertion loss (or gross noise attenuation) of not less than 4.5 dB(A) when measured inside the shadow zone whilst the reflective type barrier produced insertion loss of 1 dB(A) less than the absorptive types measured at the same location. Levels of vibration were measured with accelerometers attached to the concrete sleeper, the steel post and at different positions on the timber panel with the resulting data processed by the sound level analyser. The presence of a 10 mm thick EVA pad sandwiched between the post baseplate and the concrete sleeper provided an adequate means of vibration isolation.

Laboratory tests were undertaken in a reverberation chamber on a sample of the timber absorptive barrier panel to ascertain some of its acoustic characteristics. The test results gave a value for sound reduction index of 31 dB(A) averaged over the 1/3 octave bands between 100 Hz and 3150 Hz. Mineral fibre had been employed as the noise absorptive medium with, according to the manufacturer's technical literature, a sound absorbency coefficient of at least 0.8 measured in the 500 Hz octave band and above.

A computer model for the prediction of railway noise levels had been developed in house as part of the research and development programme and which was specific to the generation of noise by DLR trains. The effects of low level noise barriers on the wayside noise environment at the trial site as predicted by the computer model were validated by noise measurements taken on site.

Monitoring of the installation process indicated that substantial lengths of barrier could be easily installed during night time possession hours. Disturbance to local residents had been minimised by man-handling materials and plant, by using diamond drills instead of percussive drills for fixings into concrete sleepers and by instilling self-discipline in the work force for quiet working practices. It also demonstrated that there was an added benefit for track maintenance arising out of the evident ease with which the barrier could be dismantled and re-erected.

From work carried out during the site trials it was confirmed that the probable maximum value of insertion loss achievable with low level noise barriers would be between 4 and 5 dB(A). This suggested that the most appropriate application for low level noise barriers would be at sites possessing more marginal noise reduction requirements. The cost to manufacture and install low level noise barriers, bearing in mind the saving in materials quantities and the comparative ease of installation, was estimated to be one tenth of the cost of installing proprietary high level barriers at the same location. In terms of cost per decibel of each of the first 5 dB of noise reduction achieved, the low level noise barriers worked out substantially cheaper than proprietary barriers. For degrees of attenuation above 5 dB then there would be a need to consider high level barriers. In short, low level noise barriers presented DLR with a cost effective alternative to high level barriers at those sites which required more marginal noise amelioration.

A low level noise barrier system using timber absorptive panels was the chosen option for installation at known noise sensitive locations on the railway on financial, technical and serviceability grounds. The systemwide noise monitoring exercise had identified six marginal sites which required best practicable means of noise control, each with buildings in close proximity to the railway and each with noise levels exceeding policy targets by no more than 5 dB(A). DLR procured the supply and installation of these novel low level noise barriers at the six locations under one contract. A series of post-installation noise measurements indicated that generally the introduction of low level noise barriers at these sites had the effect of reducing train noise to below the target levels set by the DLR noise and vibration policy.

"Smartsound" noise adaptive station PA control system

DLR depends on a good quality public address (PA) for communicating passenger information. Initially DLR stations were generally equipped with a limited number of PA loudspeakers which broadcast messages down each platform. Variation in volume level was restricted to two settings: daytime (normal level) and night time (reduced level). During the day, PA announcements were drowned by excessive background noise, eg other trains, traffic, aircraft, etc. At night the PA system was sometimes perceived as being intrusive by local residents when the railway was being used by fewer passengers waiting on the platforms. DLR was committed to solving this problem. The objective was to minimise intrusive noise overspill from the station PA system into nearby properties and yet maintain the volume and intelligibility of announcements for passengers.

As a result, "Smartsound" was developed by DLR, jointly with a specialist electronics company, which solves the problem in three ways. Firstly, by the installation of additional loudspeakers distributed along each platform, each one operating at a lower power output level than the loudspeakers they replaced. Field trials demonstrated a reduction in sound power level of 7.5 dB(A) L_{eq} less than before at a neighbouring property.

Secondly, "Smartsound" has the capability to adapt automatically the volume of PA announcements in line with the concurrent ambient noise such that the volume level is maintained at between 5 and 8 dB(A) headroom above the constantly changing background noise level. The noise adaptive function of "Smartsound" is achieved by 'listening' to the level of background noise with a sampling microphone mounted on the station. The "Smartsound" device detects all PA announcements present and temporary suspension of the "Smartsound" function prevents the system from suffering from acoustic lock-up whereby it is unable to distinguish between the PA message and background noise. Without this, if "Smartsound" listened to both it would continue to adapt the PA output level accordingly, thereby causing the PA volume level to spiral to its maximum threshold.

Lastly, "Smartsound" uses passive infra-red (PIR) detector switches to activate only those loudspeakers in the vicinity of passengers on the platform. Each loudspeaker is equipped with a PIR sensor switch which detects passengers in its vicinity and so activates the loudspeaker to which it is attached in readiness for the next announcement. Truncated messages can cause confusion and mis-information. The "Smartsound" PIR device avoids this by sensing the presence of messages and suppressing loudspeaker activation for the duration of that message and then, assuming passengers are still present, permits the next announcement to be broadcast. The device also prolongs loudspeaker activation until the message finishes.

The advantages of "Smartsound" are that the system enhances system reliability, facilitates setting up of the required operating levels, minimises the need for further adjustment (or tampering!) and gives a constant level of performance. Applications have been made for two UK patents. The cost to supply and install the full "Smartsound" system to enhance a typical DLR two-platform station, already equipped with a distributed array of loudspeakers down each platform, is estimated to be only a fraction of the initial PA system capital investment.

Conclusions

Docklands Light Railway staff have acquired considerable specialist skills, knowledge and expertise (not least in railway noise and vibration) through ten years of unparalleled experience in the design, installation and integration of railway technology vital to the successful operation of a complex, software based automatic light rail system. Noise and vibration issues affecting, in particular, light rail networks and tramways are very different to those affecting conventional railways. The operators of urban light railways have to make a more detailed consideration of noise and vibration due to the proximity of dwellings. In recent years DLR has undertaken extensive research into most aspects of railway noise and vibration, and has used both conventional and novel technologies to succeed in resolving problems which it, in company with most other railway organisations, faces. Consequently, DLR has taken steps to make this unique expertise available to other railway operators and promoters to help them secure appropriate and cost effective solutions to their particular noise and vibration problems.