

The Vadavār Railroad in Tanjāvūr district, Madras Presidency, reported in 1836

Anantanarayanan Raman and Vancheeswar Balakrishnan

The Madras Journal of Literature and Science (MJLS, 1836, 4) carries a four-page article entitled ‘An account of a railroad laid in the Vaddavaur district’. This article refers to a temporary, c. 500-yard long railroad built in Vaddavaur (read as Vadavār) located at the confluence of Kōllidam and Vadavāru rivers. This railroad was laid to move building materials necessary for the construction of a dam – referred as the Vadavār dam – supervised by the Madras construction engineer Arthur Thomas Cotton in the 1830s. Since this article was published in the July–October issue of MJLS 1836, the logical deduction would be that this railroad was completed before July 1836. This human-pushed railway, therefore, precedes the presently recognized earliest goods-transporting Red Hills Railway, at least by a year, which operated between Chintādaripēt and Red Hills in Madras from 1837. The 1836 MJLS article on the Vadavār-railroad provides fascinating details of railway engineering of the day in the Madras Presidency that are highlighted in the present note.

Transport of heavy goods in coupled wooden wagons of ‘open-box’ types on rails has been in practice for a little more than five centuries. The Lake Lock Rail Road (LLRR), a narrow-gauge railway, operated in Britain in from 1796 to 1836, with a three-wagon train (note 1) pulled by a single horse, to move coal from Lake Lock, Stanley (53°71′N, 1°47′W) to Outwood (53°71′N, 1°50′W) (<https://www.stanleyhistoryonline.com/Lake-Lock-Rail-Road.html>; accessed on 24 June 2019). Before the LLRR, solitary wagons running on parallel wooden tracks transported mined soil in many European countries¹. Because the wooden tracks wore out quickly, flat cast-iron plates were used. Usually L-shaped plates with their platemays (the stems of ‘L’) guided train wheels. George Packer Raida-baugh’s *Origin and Development of the Railway Rail: English and American Wood, Iron, and Steel*² provides details of the science of railway engineering of the XIX century.

A train hauled by a steam locomotive was first run in England in 1804, due to the effort of Richard Trevithick (1771–1833)^{3,4}. Such trains became popular by the 1820s and this transport mode eventually changed the complexion of land transport, incidentally influencing and modifying the social and economic dynamics of human society. The design of flanged wheels suited to run efficiently on metal rails, was a remarkable scientific development, by a British inventor–mechanic James Curr (1756–1823). The science behind this invention is that the

heavier the wagons with flanged wheels rolled on metal tracks, less energy/unit mass is spent. Also equally important was that far less energy/unit mass was necessary to run a train of several wagons than to move the one hauling fewer wagons. Either single or a pair of horses could comfortably pull three connected (coupled) wagons loaded with soil at a greater speed than several humans carrying the same load on foot. This, nonetheless, does not work efficiently in rubber-tyred vehicles running on flat roads, because of fractional hysteretic energy loss and elastic stiffness⁵.

Plans for a railway in Madras (13°5′N, 80°16′E) were discussed in Britain as early as 1832 (refs 6, 7). A business enterprise, in the name and style, the Madras Railway Company (MRC), existed in Britain in the 1830s. At a meeting of the shareholders of MRC held in London on 19 March 1846, the following statement was minuted⁸. [For clarity, currently valid names and other pertinent details are included in brackets in the text below and in the quoted texts used later in this note]:

‘In 1832, the idea of forming a railroad from Madras (13°08′N, 80°27′E) to Arcot (12°90′N, 79°32′E) and Bangalore (12°58′N, 77°35′E) was suggested as one that in time might be realised, and prove a remunerating undertaking. In 1836, a report was made to the Madras Government upon the state of the internal communications of that presidency, by

Captain A. Cotton (Arthur Thomas Cotton, note 2), of the Engineers, in which he describes and recommends to Government the construction of an extensive system of railroads throughout the Presidency. In 1837, the Madras Government directed a survey of the line from Madras to Wallajahnagger (Walajah, 12°56′N, 79°8′E), within two miles (3.22 km) of Arcot (12°99′N, 79°31′E). This survey was made by Captain Worster (note 2), of the Madras Artillery, and the Madras Government strongly recommended the execution of the work to be sanctioned by the Court of Directors in this country, but financial considerations were an objection to the outlay required.’

The following text, reinforcing the above, can be found in the *Asiatic Journal and Monthly Register for British and Foreign India, China and Australia* under ‘Asiatic intelligence’ of 1836 (ref. 9, p. 79):

‘RAIL-ROADS. We are glad to learn that there is every probability of railroads being soon laid down both to the Mount (Little Mount, 13°0′N, 80°13′E) and to the Red Hills (13°11′N, 80°11′E). The Conservative (a newspaper in Britain) says an order to that effect has already passed Council; another report states, that it has received the approval of the Military Board, and waits the confirmation of Sir Frederick Adam

(Governor of Madras, 1832–1837); but we believe there is no doubt of the fact, that the estimates of both lines of road have been given in, and approved of by the authorities, and that they will be immediately carried into execution.’

The Red Hills Railway, an early goods train in India

The Red Hills Railway (RHR, also referred as the ‘Red Hills Railroad’), supervised by Arthur Thomas Cotton (see Portrait), ran India’s early narrow-gauge train to move laterite from the Red Hills (note 3) to Chintādaripēt (Chinnattari-péttai, 13°4′N, 80°16′E), a Madras-city suburb in 1837. Possibly, the RHR ran with a William Avery rotary steam-engine locomotive¹⁰. However, a 1900 reference indicates that the RHR was animal-pulled¹¹. An 1854 Madras map (<https://wiki.fibis.org/w/File:PlanofMadrasanditsenvirons.1854.v3.png>; accessed on 24 June 2019) displays a portion of RHR running parallel to Captain Cotton’s Canal (named after Arthur Cotton), which connected to Cochrane’s Canal (note 4). The plan of extending RHR to the Little Mount, also proposed by Cotton, did not materialize. The *Madras Gazette* of 4 May 1836 includes a reference to this proposal – a ‘tramway’ to transport stone quarry extracted in the vicinity of Little Mount and St Thomas Mount (13°N, 80°11′E), broadly Pallāvaram region (12°98′N, 80°18′E)¹² – for road construction in Madras city¹³ (note 5).



Portrait: Arthur Thomas Cotton
Source: E. R. Hope & W. Digby (1900)

Until September 1838, this proposal remained unapproved with the government at Fort St. George. It was, however, rejected citing reasons of high cost. Elizabeth Hope – Cotton’s daughter – refers to RHR running between Chintādaripēt and the Red Hills in her father’s biography (ref. 11, pp. 66–67):

‘Circumstances arose which prevented the completion of this line (extension to a new destination beyond Red Hills?), but afforded considerable practical experience, which was of considerable use to him in the execution of Godavari works years after, where railway lines played an important part in facilitating the prompt construction of the great dams’.

Cotton made phenomenal efforts to establish a railway in Madras Presidency. His proposals to the Government of Madras included linking Madras with various towns within the Presidency and other principal Indian towns. An ‘Integrated Transport System’ proposal linking Madras with Bombay (19°08′N, 72°88′E) via Wallajah, Nellore (14°26′N, 79°59′E), Bangalore, Bellary (15°8′N, 76°55′E), and Poona (18°31′N, 73°51′E) covering a distance of *c.* 860 miles (1380 km) made in 1836 was a grand one. In the *Railway Minute* of 20 April 1853, James Andrew Broun-Ramsay (Dalhousie, Governor General of India, 1846–1856) offered a plan connecting principal Indian cities by trunk lines. For the Madras Presidency, he proposed a route from Madras city to the west coast with branches to Bangalore and Mettūpālayam (11°30′N, 76°95′E), while another line was to proceed northwards through Cudappāh (Kadappā, 14°47′N, 78°82′E) and Poona to Bombay, thus linking Madras with Bombay¹⁴. Based on Broun-Ramsay’s *Minute*, the Madras–Bombay rail service – what Cotton proposed in 1836 – materialized a decade and a half later, with some modifications¹⁵.

Against such a background, the present note refers to a four-page paper¹⁵ that describes a railroad established in Vaddavaur (read as Vadavār, Tanjāvūr District, 10°46′N, 79°54′E, presently Pazhayār, Nagapattinam district, Tamil Nadu) in either 1835 or early 1836, which pre-dates the RHR at least by one year. No author name occurs in this article (Figure 1). Highly likely, it was writ-

ten by Cotton himself. Alternately, the article could have been written by John Thomas Smith of the Madras Sappers and Miners, who was Cotton’s first assistant in the Kōllidam Annicuts Project (hereafter spelt ‘anicut[s]’; note 6) in 1835–1836.

The Vadavār Railroad, 1836

The Vadavār railroad in Tanjāvūr district was built as a temporary facility to transport the materials required in building the dam at Vadavār (Figure 2). This railroad was 426 yd (390 m) long. Of this, a 250 yd (228.6 m) long rail track was built using I-section beams of cast iron. The remainder was built using I-section beams of wrought iron (bar iron) (note 7). These tracks were fixed onto slats of Asian palmyra tree trunk (*Borassus flabellifer*, Arecaceae). The slats were bedded lightly to the soil ensuring stability for the overlying rails. Wherever cast-iron rails were used, their ends were not joined because their weight and shortness served the purpose. Wherever the wrought-iron rails were used, their ends were joined using ordinary bolts to prevent their lifting on applying heavy loads, since these pieces were lighter than the cast-iron beams.

‘Fish-bellied’ and ‘parallel’ cast-iron rails were used in this project (Figure 3). The rail gauge was less than 4′ (1.21 m, 3′6″?), which has been estimated from the available dimensions of the used open-box wagons. The following details are available (ref. 15, p. 347):

‘... No. 1, a fish-bellied rail, weighing 35½ lbs, (16.12 kg) broke on the application of one thousand two hundred and seventy four lbs (578 kg). Its deflection, immediately before breaking, was three-eighths of an inch (0.95 cm). No. 2, a parallel rail, beaded at the bottom and weighing 37½ lbs (17 kg) broke with one thousand eight hundred and forty-eight lbs (838.24 kg) and bore a deflection of five-eighth of an inch (1.59 cm). The difference of resisting power in each of these, as compared with the respective weights of composing material, will not fail to be at once perceived; the foundery (foundry) at Porto Novo, and sold at the rate of one hundred rupees per ton, including carriage’ (note 8).

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Four open-box wagons (referred variously: ‘carts’, ‘carriages’¹⁵) on wooden frames resting on axles and equipped with friction wheels were used (Figure 4). Three of the wagons carried a load of 732 lb (332 kg) each and the fourth carried 943 lb (428 kg). A wagon bearing the full load (1560 lb = 707.6 kg) was considerably below the ‘braking power’ (term used in the *MJLS* paper¹⁵, instead of ‘load-bearing capacity’ used earlier in the same paper). Each wagon was pushed by two men and the train reached a maximum rate of 15 miles/d (24.14 km/d).

Each of the larger wheels made of cast iron and fixed to axletrees was a foot (30.5 cm) in diameter (note 9). The wheels bore a circumscribing flange, which projected ¼" (0.64 cm) from the interior rim. Each friction wheel was 4¾" (12.06 cm) in diameter.

On the efficiency of this railroad, the paper mentions (ref. 15, p. 348):

‘From the experience which was attained on this road, it is impossible to state the extent of advantage which will be derived from the substitution

of these friction wheels, as a working place for the axles, ... for the carriages employed were altogether of such rude construction, as not to hold out material for the formation of a fair judgment. Yet, it may be useful to state, that, in order to overcome the inertia and friction of a carriage, whilst standing on the rails, a declivity of one in seventy was required, and also, that, although in constant use for two months, and travelling at the daily rate of fifteen miles, their axletrees were but slightly worn.’

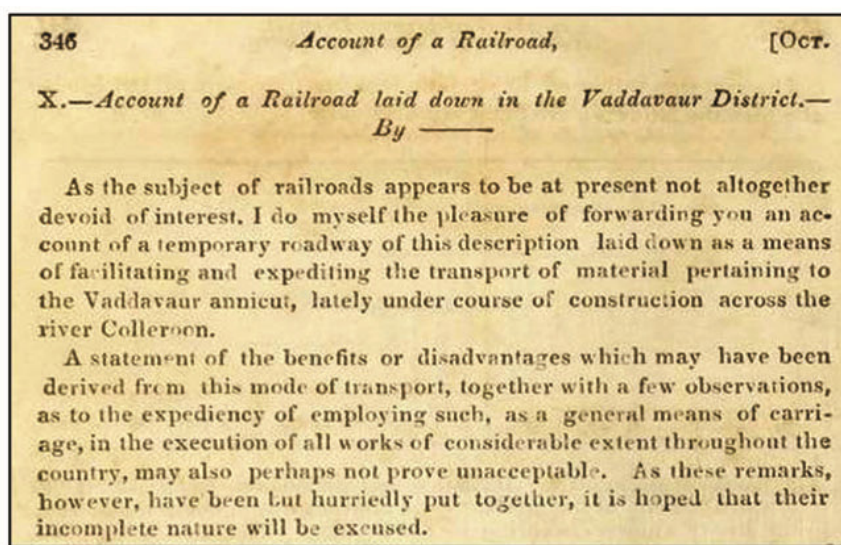


Figure 1. A section of the title page of ‘Account of a Railroad ...’¹⁵.



Figure 2. Map showing River Kāvéri and its branches. ★ Approximate location where the dam was built in 1835–1836. Source: ref. 33.

The *MJLS* paper¹⁵ concludes with the statement that this railroad was a viable and an economically productive means of transport. That this railroad employed 900 people in three months. The iron used in this project was recoverable and resaleable at the rate of Rs 40 per tonne on completion of project. A costing table towards this railroad (overall expenditure: Rs 1259, 12 annas; note 10) is also available. A comparative costing of the same railroad, had it been managed using animal power recruiting 9000 bullocks, is also supplied.

Remarks

Vadavār village was named so because of Vadavāru (a Kāvéri distributary) that flows from the north (vada, vadakku – north, āru – river, Tamizh). Presently, this village is known as Pazhayārai, Pazhayār (pincode 612 703).

Water to the Veeranarayanapuram lake (presently Veeranam lake, 11°20'N, 79°32'E, constructed c. 10th century AD) is supplied by Kōllidam via Vadavāru. The Kōllidam skirts around Srirangam (10°87'N, 78°68'E), proceeds eastward, and drains into the Bay of Bengal at Pazhāyār¹⁶. In the 1820s, British engineers (note 11) found that the waters of River Kāvéri had an escalating tendency of draining into Kōllidam via the Ūllār channel, which they expected would dry the southern sections of this landscape over time¹⁷. Cotton proposed building two anicuts: the Upper Anicut at the head of the Kōllidam diverting some water into the Kāvéri and securing water for agriculture for use in Tiruchirappalli district (10°48'N, 78°41'E) and the Grand Anicut, a bigger one, c. 110 km south of the Kōllidam to intercept and supply water to the southern segments of South

Arcot district (11°30'N, 79°25'E) (note 12)¹⁸. These anicuts, built in 1835–1836, eased these districts from the ravages of famines in later years, such as the Great Famine in the Madras Presidency of 1876–1878. Nathaniel William Kindersley, Collector of Tanjāvūr, 1828–1839, speaks of Cotton (ref. 11, pp. 52–53):

‘... not an individual in the province who did not consider the upper anicut the greatest blessing that had ever been conferred upon it, ... the name of its projector would in Tanjore (Tanjāvūr) survive all the Europeans who had been connected with it.’

Early railways were laid out with gentle gradients, since the locomotive and animal haulages were low in tractive effort. To overcome steep slopes, measures such as dividing the load, attaching additional banking engines, using a more powerful and a heavier engine for negotiating steep gradients, strengthening tracks and allowing greater speeds of trains, were applied in the later decades of the 19th century. In such a context, incorporation of friction wheels in the wagons that ran in the Vadavār railroad in 1836 appears as a smart move.

When steam-engine pulled wagons replaced horse-drawn wagons on metal

rails in America and Europe, how the wagon wheels would hold onto rails with sufficient friction, especially while negotiating and overcoming slopes, was a worrying factor for railway engineers¹⁹. The ‘mechanical traveller’ (MT, ‘steam horse’) designed and developed by William Brunton of the Butterley Ironworks, Derbyshire, UK in 1813, solved this problem to a large extent. Brunton built the MT with its pair of steam-powered legs at the rear, which pushed the engine on rail tracks²⁰ (note 13; see https://en.wikipedia.org/wiki/Steam_Horse_locomotive#/media/File:Bruntons_Traveller.jpg for an illustration). That these MTs proved useless in the following decade is a different story. Yet the MT is striking in terms of its science and technology. Since then, railway engineers were interested in the science of friction between the wheel and rail. The friction coefficient determined how fast a train could accelerate, the distance it needed to brake and stop, and the load of passengers and goods a train could carry. This necessitated incorporating a ‘bearing’ at the ‘axletree–wheel’ junction of the wagon. Plain bearings offered a high resistance for easy spinning of rail-wagon wheels²¹. Therefore, railway engineers sought solutions that minimized resistance. With the start of the Baltimore &

Ohio Railroad (the oldest railroad of America, founded in 1828, operational from 1830), this problem of minimizing friction at the axles was seen as an acute one. Ross Winans, a wheat farmer and an ingenious inventor–mechanic of Baltimore, USA, solved the problem. William Howard²² had previously developed a friction wheel fixed to the exterior of the running wheel. Winans improved the Howard design by attaching the friction wheel to the inner edge of the axletree^{23,24}. A line sketch illustrating Winans’ friction-wheel design is available in White²⁵ (p. 515). Winans’s friction wheel ran out of the interest of railway engineers shortly thereafter²⁵. What impresses in the Vadavār railroad is the incorporation of the friction wheel, using Winans’ design, made six years earlier. The friction wheels used in the Vadavār rail wagons could be seen as an early form of unlubricated roller bearings.

The Vadavār rails were laid out in grooves cut out of *Borassus flabellifer* trunk slats laid at 5’ (1.52 m) spacing, which were bedded in the ground. This reminds us of the Barlow saddleback rail, developed by William Henry Barlow (1812–1902, English railway engineer), used in the first rail line laid between Sydney and Parramatta (New South Wales, Australia) in 1855. The Barlow rail design differed from the type of the rails that are currently used. The Barlow rails were laid directly onto a roadbed (either sandstone or basalt, also referred as ‘ballast’) without any wooden sleepers²⁶. Unjoined wrought-iron Barlow rails were used by the Great Western Railway in Britain in 1853. They were bedded directly in the ballast without any gauge ties and caused much trouble (A. Hayward, pers. commun., e-mail, 21 November 2019).

The costing tables included in the 1836 *MJLS* paper¹⁵ indicate the overall expenditure towards labour involving either 900 humans or 9000 bullocks. This costing needs to be factored as a distributed cost over 90 man-days of the labour involved. In every possibility, ten humans were employed, who worked for 90 days. A similar factoring would be necessary with the bullocks as well.

The use of *B. flabellifer* slats to secure the iron tracks in the Vadavār railroad is strange, because today we know that workability of this timber using either machine tools or hand tools is difficult. Moreover, the timber of *B. flabellifer*, a

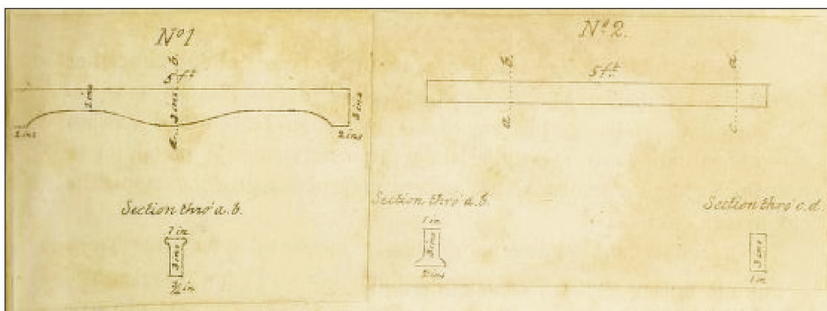


Figure 3. Fish-bellied and parallel cast iron rails.

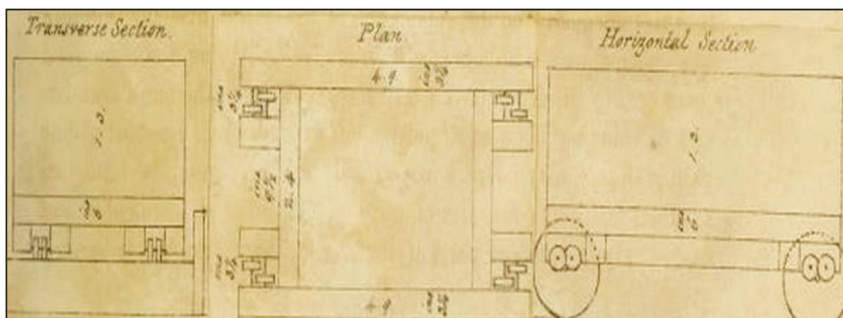


Figure 4. Transverse and vertical sectional views of a wagon.

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monocotyledon with a tree habit, can be classified neither as a softwood nor a hardwood (The Wood Database, <https://www.wood-database.com/black-palm/>; accessed on 24 November 2019). This material was used in the Vadavār project (1836) similar to sleepers ('ties' – American) used in rail tracks of today. Strapping iron rails to wooden slats was the recognized practice in rail-road building in the 1830s and 1840s. In America, cypress and cedar woods were the material of choice because these woods would not rot quickly²⁷. Abundant availability of *B. flabellifer* in the Madras Presidency could have been the driving reason for its choice for use as sleepers in the Vadavār railroad project. However, currently we know that the *B. flabellifer* timber bears high compressive and tensile strengths²⁸ and lesser susceptibility to rotting²⁹.

The intent of the sentence fragment 'by experiments which these rails afforded, ...' (ref. 13, p. 347) is not clear: does this refer to the 'experimental railway' trialled earlier by Cotton in Chintādrīpēt, or to the few trials made in Vadavār before the launch of the railroad? Simon Darvill (Indian Railways Fan Club, UK) has spoken about an experimental railway trialled by Cotton in Madras in the webpage <India's First Railways> (<https://www.irfca.org/docs/history/india-first-railways.html>). While reviewing the present paper, Darvill commented (Simon Darvill, pers. comm., e-mail, 7 July 2019):

'The timeline of Vadavār, Red Hills, and the Experimental Railways is a conundrum. I think the order would be Experimental, Vadavār, and Red Hills. My feeling is that the trials that you refer to prior in Fig 2 are what is called the Experimental Railway. Then came the Vadavār, then finally the Red Hills. So whilst the Experimental Railway is probably technically India's first railway, it would be fair to say that the one at Vadavār is the first railway used in anger. Red Hills is a distant third!'

Conclusion

Although not a passenger train and not hauled by a steam locomotive, the Vadavār railroad, established to transport materials to the then newly coming-up

dam at the Vadavāru–Kōllidam confluence, supplies fascinating details of the science of railway in the early decades of 19th century India. This railroad could have been inspired by the railways operating in Europe and America for transporting heavy goods at that time. The critical difference, however, was that a majority of the European and American railways were horse-pulled, whereas the Vadavār railroad was human-pushed. The two costing tables evaluating the economic efficiency of using human power to move the train vis-à-vis the purported use of animal (bullock) power should interest economic historians more than *Current Science* readers. Building open-box wagons to move large volumes of load (c. 1000 lb = 454 kg) does not excite. But the axletrees, flanged iron wheels, and importantly, the friction wheels, certainly do.

Railways transporting humans flourished in the Madras Presidency in subsequent years. The Indian Tramway Company (ITC) operated a line from Arakkōnam (13°04'N, 79°40'E) to Kānchipuram (12°82'N, 79°71'E) from 1860. The ITC became the 'Carnatic Railway' (CR) in 1870. The CR merged with the Great Southern of India Railway (GSIR) in 1872. The merged CR and GSIR were renamed as the South Indian Railway (SIR) in 1874. The Arakkōnam–Kānchipuram line was constructed with a 3'6" gauge, but in the following years, the Secretary of State for India entered into a contract with the company for the conversion of their light, narrow gauge rails into a 5'6" (1.71 m) wide line and to extend it up to Cuddalore (11°75'N, 79°75'E)²⁷. And the story goes on.

Notes

1. Train (noun): a connected line of railroad cars either with or without a locomotive. <https://www.merriam-webster.com/dictionary/train> (accessed on 4 July 2019).
2. Arthur T. Cotton (1803–1899) joined the Madras Engineers Corps in 1821 as an assistant engineer. His first assignment was the management of Pāmban isthmus between mainland India and the island of Ramésaram (9°17'N, 79°18'E) off Mannār (8°58'N, 79°53'E), northwestern coast of Sri Lanka. In 1828, Cotton contributed substantially to improving irrigation in Tiruchirappalli, Tanjāvūr and South Arcot districts of the Madras Presidency. He also attended to regulating irrigation from the Godāvāri and Krishna rivers.

Worster mentioned here is William Kinnaird Worster (1811–1882) of the Madras Army, who, for some time superintended the Western Roads, Madras.

3. Laterite is iron- and aluminium-rich rock commonly found in southern India, a hard material used by humans extensively in the construction industry for centuries. Francis Buchanan-Hamilton described this rock from Angādipuram (10°58'N, 76°13'N) in 1807 (ref. 30). Robert Cole (Surgeon, Madras Medical Establishment, editor of the *Madras Journal of Literature and Science (MJLS)* from 1836, and an amateur geologist) published an article on laterite (also referred as iron clay) found in the Red Hills in *MJLS* in 1836 (ref. 31). Red Hills in Madras gets its name because of the red, lateritic soil, referred as 'Yérracōndah' (Telugu, 'yérra'–red, 'cōndah'–hillock) during pre-British days.
4. The Cochrane's Canal was widened and deepened enabling country-boat navigation for commerce. This canal came to be known as the Buckingham Canal from 1878.
5. At Tirusūlam (12°58'N, 80°10'E, Pallavaram Hills, c. 10 km southeast of St. Thomas Mount) open-pit mining to extract charnockite – an orthopyroxene granite – for road works is done even today.
6. 'Annicut' ('anicut') is an anglicized Tamizh word 'añai-kattu', which refers to any construction – dam or barrage or weir – that regulates water flow across a flowing-water system.
7. Cast iron is an alloy that includes C, Si and Mn. This type of iron is made by smelting iron ore in a blast furnace. The molten iron is then cast as bars, the 'pigs', which are melted again along with the alloying materials and recast. Bar iron is wrought iron supplied as bars.
8. Porto Novo Iron Works, Parangipéttai (11°49'N, 79°76'E) operated between 1830 and 1859 (ref. 32).
9. 'Axletree' and 'axletrees' are terms that evolved from the Middle-English term 'axiltre' (AD 1100–1500) referring to the spindle connecting two oppositely placed wheels making them spin concurrently.
10. Before decimalization of Indian coinage in 1957, an Indian rupee consisted of 16 annas, one anna of 12 pies.
11. Engineers serving with the Madras Engineers Corps were known as Madras Engineers, who used the letters 'M.E.' after their names. By the mid-19th century, this practice changed. Indian engineers were authorized to use 'R.E.' (Royal Engineers). Arthur Cotton used M.E. during the initial days and R.E. in later days.
12. The province of Arcot was annexed by the English East-India Company, when Ghulam Muhammed Ghouse Khan, the Nawab of Carnatic, died in 1855. The

- EEIC cleaved the province into North and South Arcot districts for administrative reasons. In 1993, the Government of Tamil Nadu further cleaved South Arcot district into Cuddalore and Vizhu-puram districts.
13. The patent application for the 'mechanical traveller' was rejected by the British Record Office in 1813, since the application lacked mechanical details and an explanation of parallel motion.
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Anantanarayanan Raman is with the Charles Sturt University, PO Box 883, Orange, NSW 2800, Australia; Vancheeswar Balakrishnan lives at C-23, MES Colony, Venkatapuram, Secunderabad 500 015, India.*

*e-mail: anant@raman.id.au