triangulum

Lighthouse City: Manchester
Impacts and Learning
Project Report - Mobility

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The Manchester Triangulum Project - Mobility

Summary

Funded from the H2020 European Union Research & Innovation Programme, the Triangulum project was launched in 2015 and completed in January 2020. This involved over 20 international partners worked together to demonstrate smart city solutions, carbon and energy savings across 3 cities; Manchester (UK), Eindhoven (Netherlands) and Stavanger (Norway). The work programme covered three areas: energy, mobility and ICT. Manchester City Council (MCC) was the lead partner for the Manchester partners - working with Manchester Metropolitan University (MMU) and the University of Manchester (UoM).

The project aimed to decouple carbon emissions from growth in the Oxford Road Corridor area (Manchester's innovation district located south of the city centre and home to a unique concentration of knowledge, business and cultural assets) enabling it to become one of the largest knowledge driven low carbon districts in Europe. The objective is to create a low energy district with renewable electricity generation, battery storage and smart energy management, using electric vehicles (EVs) and electric cargo bikes (e-cargo bikes) for mobility and generating data for engagement and further planning.

Commissioned as an external report, this document looks at the mobility element of the project – developing EV and e-cargo bike use in the MCC, MMU and UoM fleets.

It assesses the contribution the Triangulum Project has made to reducing carbon emissions from transport, and associated improvements to air quality. It also looked at the changing travel behaviours in ways which contribute to growth without increasing carbon emissions.

Context

MCC, MMU and UoM are all significant employers located in central Manchester and all manage sites which attract large numbers of people – from students to shoppers and visitors - in the urban core. All three require and manage a number of vehicles in the Oxford Road Corridor area.

In parallel with the Triangulum Project, this corridor has been targeted for air quality and urban realm improvements because it had reached unsustainable congestion and air quality levels.

Changes to Oxford Road included cycle infrastructure with stretches of protected cycle lane and better pedestrian access. Sections of the road are closed off to general traffic during the day (6am – 9pm), allowing only buses, cyclists and taxis. This delivers faster bus journeys and ensures services are more punctual and reliable, while improvements to cycling facilities along the road make it easier and safer for more people to ride along this popular route. From 9pm to 6am general traffic is able to go down Oxford Road. These changes were implemented in late 2016.

Whilst the improvements have had significant positive impacts on Oxford Road itself, it has required new working practices to deliver services such as maintenance or delivery to the sites split across the route - the two universities' in particular have numerous sites on either side of the Oxford Road thoroughfare. Some routes between sites have become significantly longer for cars and vans for instance – which increases fuel consumption and therefore emissions.

This document looks at the development of the fleets of all three organisations, the impacts of electrification and e-cargo bike use directly on emissions as well as on working practices, travel behaviour and attitudes to future travel and transport.

In addition, it also examines how fleet and organisational policy and practice amplifies positive impacts, where barriers exist and steps that can be taken to overcome them.

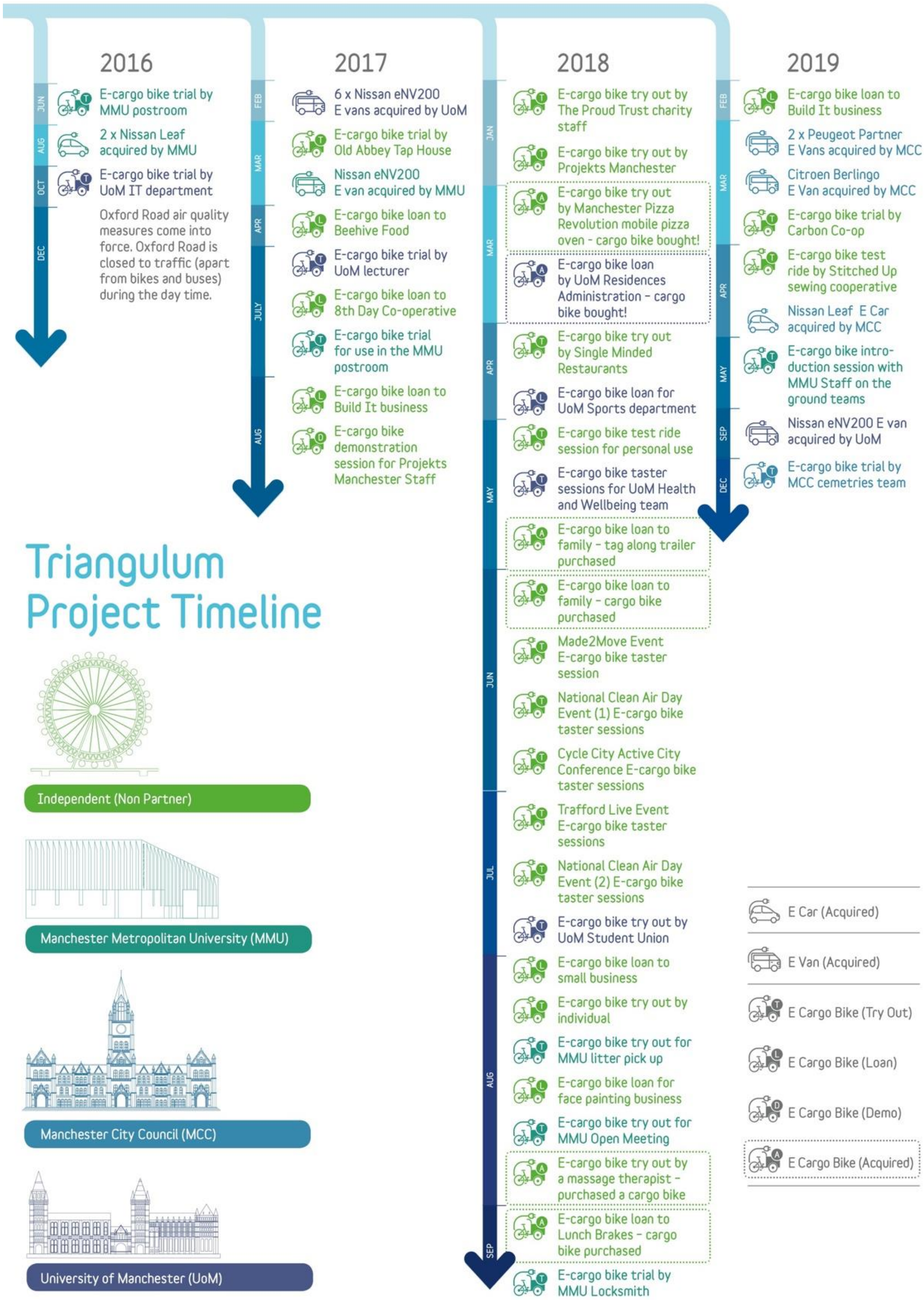

Figure 1: Triangulum project timeline

Vehicle Fleet

Triangulum enabled the partners to acquire EVs and a fleet of e-cargo bikes:

- 14 electric cars and vans
- 6 e-cargo bikes[1]

This represents 40% of EVs used by the three organisations and 3/4% of their total fleet.

Figure 2: Total size of Triangulum partners' fleet showing proportion of EVs and Triangulum EVs

The EV fleet across the three organisations comprises 35 vehicles including electric cars, vans and a landscaper. This represents almost 10% of the total fleet of around[2] 364 vehicles.

The fleets are relatively highly electrified compared to the national fleet. Of the 38.4 million strong UK fleet only around 265,000 vehicles are battery EVs – less than 1%.[3]

This has been enhanced by the Triangulum project. The project has also enabled the study of the impacts of electrification in terms of emissions reduction and behaviour change.

The differing approaches and policies of the three organisations enables comparison of different regimes and their impacts on emissions and on the behavioural element of EV and e-cargo bike adoption.

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[1] Fleet modifications took place in the duration of the project

[2] Fleet numbers varied over the period in accordance with organisational need

[3] Total UK vehicle numbers: https://assets.publishing.service.gov.uk/government/uploads/system/uploads/attachment_data/file/812253/vehicle-licensing-statistics-january-to-march-2019.pdf and total cumulative EV registrations: https://www.nextgreencar.com/electric-cars/statistics/

E-cargo Bike Fleet

There was no history of e-cargo bike use across the three organisations, so rather than introducing e-cargo bikes into each organisation separately, the project leased a small fleet of trial e-cargo bikes. This meant that staff and a wider group of individuals, social enterprises and small businesses were able to try the bikes for work travel or to make deliveries. This approach reflects the step change in working practices required to use e-cargo bikes and the need for education and trial before change can be achieved. The e-cargo bikes trials were managed by Manchester Bike Hire via a contract from MCC.

Manchester City Council

Triangulum vehicles

Four EVs were acquired as part of the Triangulum project: three electric vans (two electric Peugeot Partners and one electric Citroen Berlingo) and one electric car (a Nissan Leaf). Two replaced diesel vans (a Transit and a Connect) and two are new requirements.

The four e-cargo bikes were also available, however there was little take up until towards the end of the project when cemeteries undertook a trial.

Context

The MCC fleet consists of around 230 vehicles from mopeds, cars, small and medium vans plus goods and utility vehicles (not heavy goods vehicles). The fleet is a mixture of owned and leased vehicles and fluctuates in line with the Council's needs.

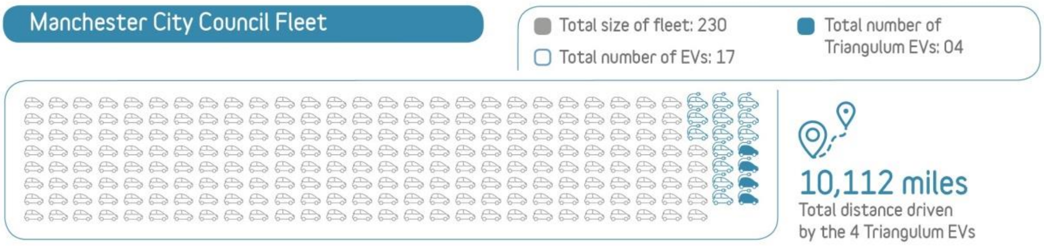

Figure 3: Total MCC fleet showing proportion of EVs and Triangulum EVs

Whilst the Triangulum EVs have expanded the electric fleet, they are not the only EVs. The electric fleet includes an electric buggy to move people attending funerals around the cemetery and some older electric bikes used for staff transport in the cemetery grounds. In addition, the council supports the social housing provider Northwards Housing with fleet management services. Their fleet of diesel vans has been replaced with electric vans, some additional facilities vans are electric Nissan eNV200s and three of the car fleet are now hybrids.

MCC has a fleet manager who manages new acquisitions, training and maintenance and where possible within funding constraints, is electrifying the fleet. This has included a pool EV on a three year lease previously. However this was not replaced and staff were given vehicle allowances instead.

Trips

The four EVs are used in a variety of ways. One is used by the Environmental Protection team as a shared vehicle for outreach visits, one by the Markets team as a shared vehicle for travel between sites and to suppliers and the other two by the Facilities team to attend maintenance repairs, for cleaning and security trips.

Case Study: MCC Markets Van

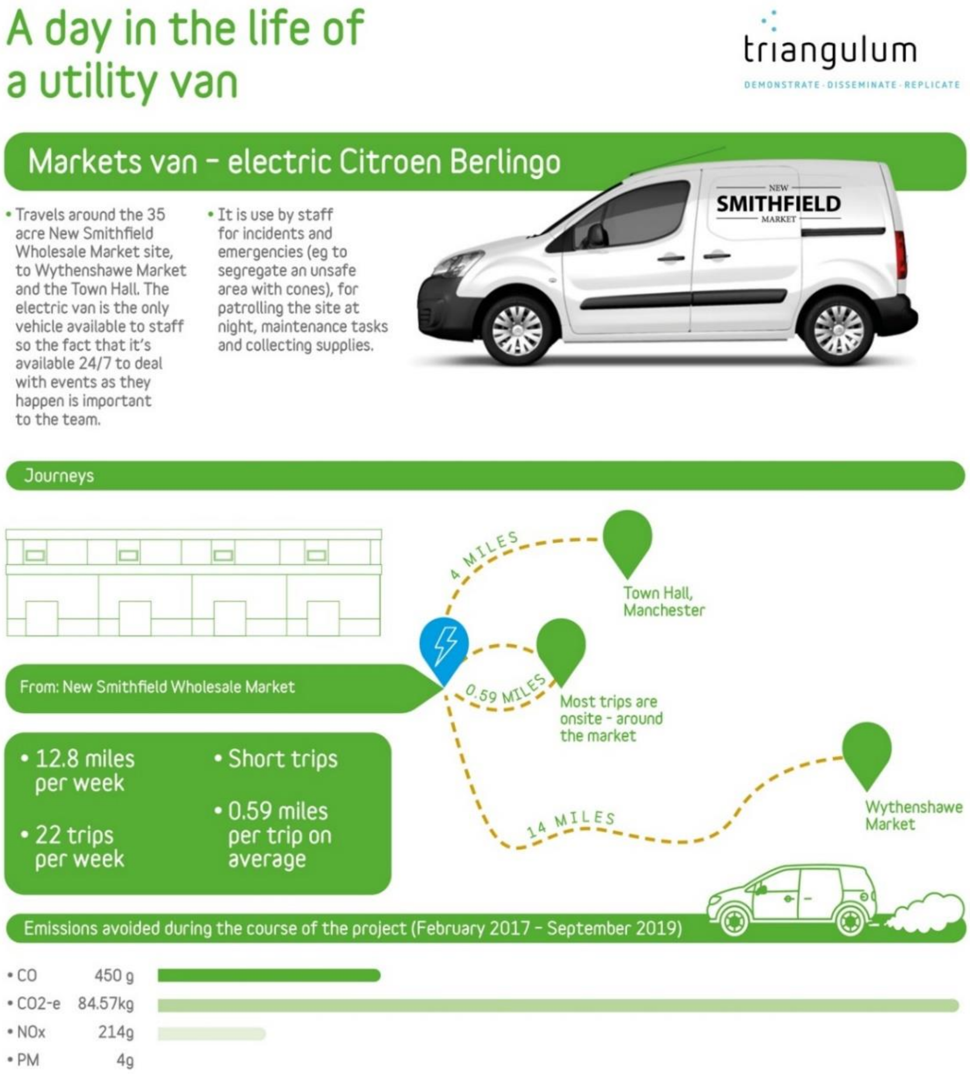

Figure 4: Case study illustration showing driving patterns of MCC markets van

Impacts

The total mileage of the four MCC Triangulum vehicles from their first trips in March 2019 to the end of the project (December 2019) was 10,112 miles.

The vans would cover between 13 miles per week (Markets van – see case study above) and 127 miles per week (Facilities van). The Nissan Leaf used by Environmental Protection would average around 55 miles per week.

During the course of the project, the vehicles represented a reduction in CO_2 emissions of 1.9 tonnes and avoided contributing 4.85kg of oxides of nitrogen, 81g of particulate matter and 10.19kg of carbon monoxide to the air in Manchester.

Emissions Not Emitted

Manchester City Council Fleet

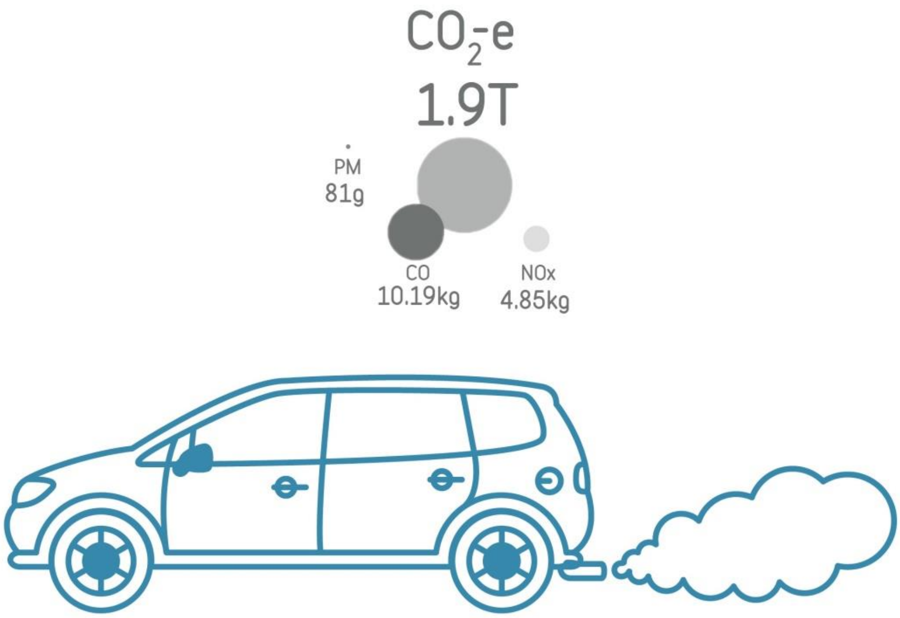

Figure 5: Emissions avoided by the MCC vehicles acquired through the Triangulum project

Users were all very positive about the experience of using the EVs.

"Surprisingly quiet, easy to use. Not the experience I was expecting - more positive than negative. Have driven old style milk float type so not like that!"

"Comfortable, easy to drive and non-polluting"

"It is surprisingly responsive, and eerily quiet"

Manchester Metropolitan University

Triangulum vehicles

Triangulum funded 2 Nissan Leaf electric cars in 2016 and MMU funded a third. This increased the EV fleet to 10 in total, augmenting an ongoing policy to move to EVs where possible.

In addition, one member of staff obtained an e-cargo bike for work journeys.

Context

MMU has a fleet of 24 vehicles, including minibuses and assorted size vans for services like catering, moving furniture and removing waste or in the course of activities (sports or field trips). The fleet is gradually being electrified and the funding from Triangulum has both enabled acceleration and helped give project partners insight into the benefits and efficiencies of using a pool vehicle system.

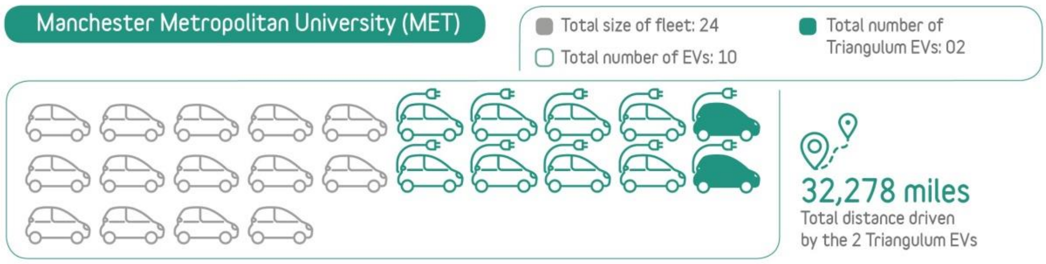

Figure 6: Total MMU fleet showing proportion of EVs and Triangulum EVs

A fleet manager oversees the fleet and has developed the vehicle policies in line with the University's environmental and staff policies. Pool vehicles are provided to enable people to do their jobs without driving to work. This reduces pressure on the limited amount of parking (which is prioritised for staff who have access issues due to disabilities or other circumstances). It also contributes the organisations carbon reduction goals.

Trips

The EVs are used as pool vehicles for diverse purposes by a wide range of people.

They can be used for outreach visits (e.g. recruiting students), by the Sports Faculty staff to attend sports events, by support staff for supplier visits and also for meetings, events and training.

The vehicles have a telematics system which enables them to be booked by staff using the Enterprise car club/pool car management system. In theory it should be possible to see the level of charge remotely via the portal, however this has not yet been implemented.

An e-cargo bike is used by a member of the site maintenance team who is a joiner/locksmith.

Case Study: MMU Pool Cars

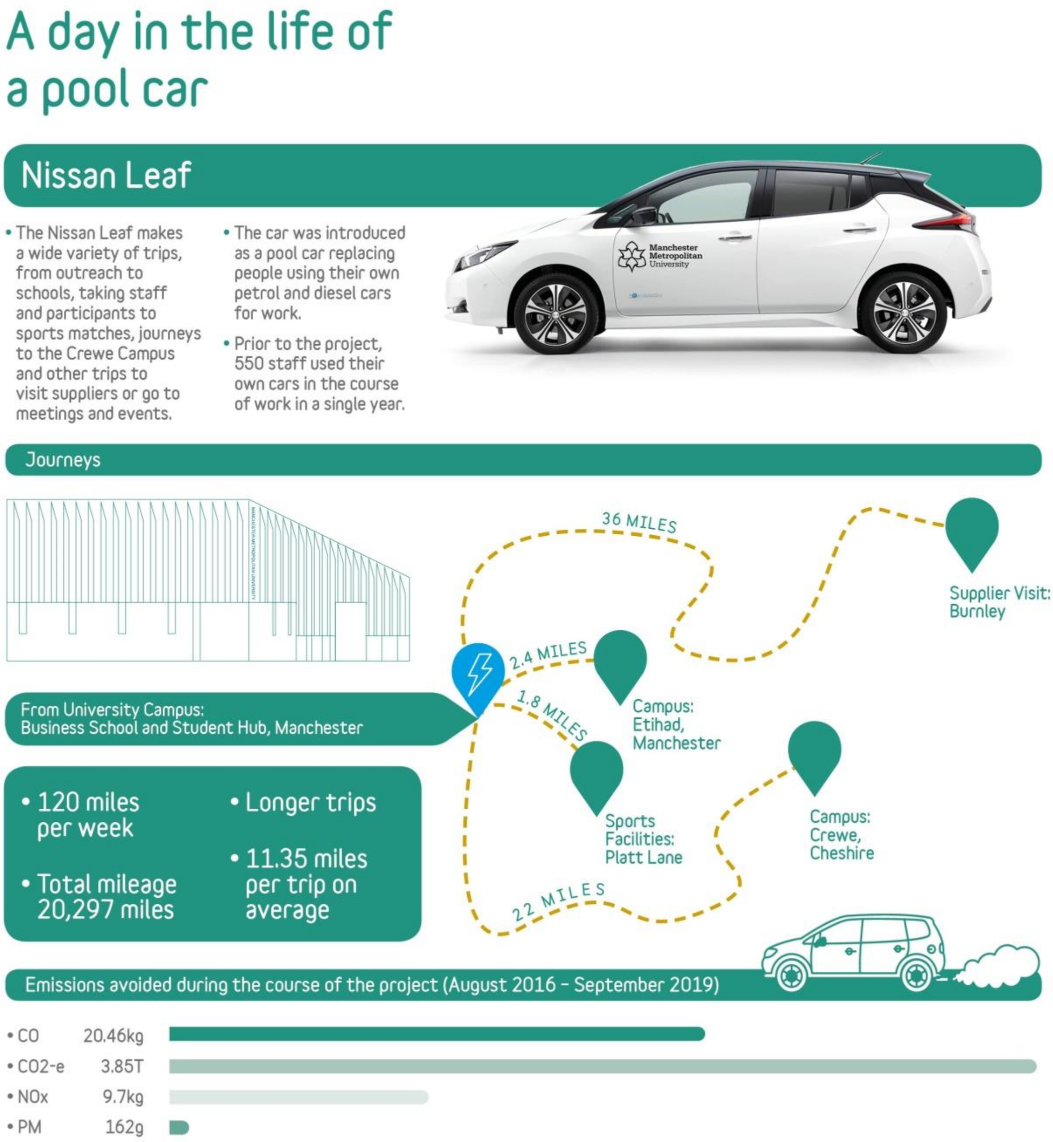

Figure 7: Case study illustration showing driving patterns of a MMU Nissan Leaf

Impacts

The total mileage of the two MMU Triangulum vehicles during the project (August 2016 to November 2019) was 34,278 miles.

The cars would cover between 83 and 120 miles per week.

During the course of the project, the vehicles represented a direct reduction in CO_2 emissions of 6.5 tonnes and avoided contributing 16.45kg of oxides of nitrogen, 274g of particulate matter and 34.28kg of carbon monoxide to the air in Manchester.

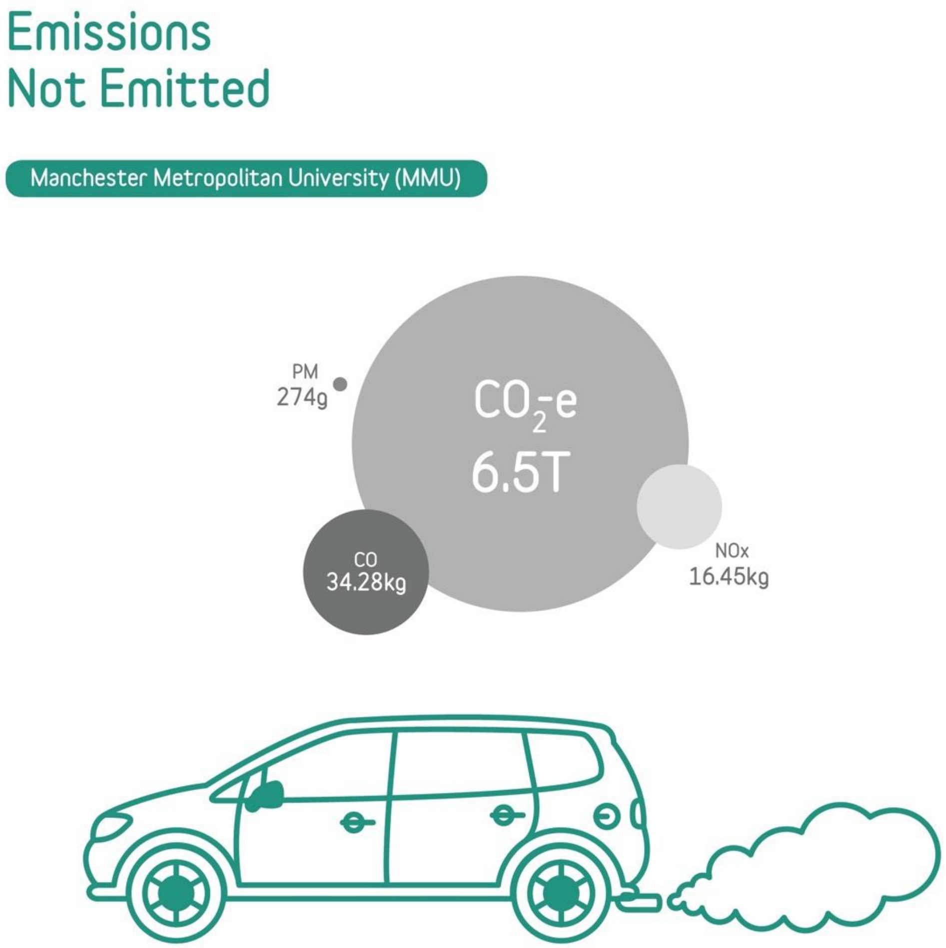

Figure 8: Emissions avoided by the MMU vehicles acquired through the Triangulum project

A number of people responding to the survey about their use of the pool cars noted a change in their travel behaviour since the pool car scheme was launched.

18% of people surveyed changed their travel to work as a result of the pool car scheme – 9 of the 51 respondents. Of these 8 reduced the amount they drove and increased their use of public transport and active travel completely or partially replacing driving. One occasionally used the pool cars to drive home in order to continue to an event the following day.

Selected quotes from these people indicated the impact of the pool cars on people's travel habits:

"Since I know the pool cars are available to use for work events I sold my car."

"Take more responsibility to find green travel methods"

"I use the pool cars for meetings off site mainly. I think there great for getting around the city. I use to drive in to the city but decided to make the commute by train for two reasons a) the pool cars made me think about more sustainable travel b) traffic in and around Manchester is awful."

"It means I can use public transport to get to work, then use cars to get to visits"

"I get bus to work and then collect pool car. I have no parking permit and therefore no access to a personal vehicle for work."

It was not possible to identify individual journeys and hence there are no granular details of journey lengths for these people. This means it is not possible to calculate a total figure for all the emissions reduction associated with their change in behaviour.

However, during the course of an interview, one member of staff discussed how he switched his daily journey from Crewe to central Manchester from car to train. This represents a weekly figure of 350 miles or 14,700 miles per year[4]. Such a switch implies avoiding the emission of 2.3 tonnes of CO_2 from driving per year. Over the three years that the pool cars have been in place this represents 6.9 tonnes of CO_2 emissions avoided - meaning this switch alone doubles the amount of CO_2 emissions avoided for the MMU scheme.

It highlights that the role of these vehicles in promoting travel behaviour change is considered as important as the direct emissions avoided by the pool vehicles themselves.

Whilst the direct emissions avoided can be calculated, the indirect emissions avoided by people changing their travel behaviour as a result of the pool car scheme could be many times that.

[4] Based on 42 weeks per year

University of Manchester

Triangulum vehicles

The Triangulum project enabled the lease of seven electric vans – all Nissan eNV200s in February 2017. The new electric vans enabled six diesel vans aged between 3 and 11 years to be disposed of. The seventh van was acquired in 2019.

When the lease expired in September 2019 the six initial vehicles were returned. Departmental budget constraints meant that they were replaced with internal combustion engine (ICE) vehicles.

One e-cargo bike was purchased via the project for a member of staff managing the halls of residence.

Context

The University fleet totals 110 vehicles including faculties, residences, IT services, maintenance and libraries vehicles plus minibuses and 8 utility vehicles for mowing/landscaping and street cleaning.

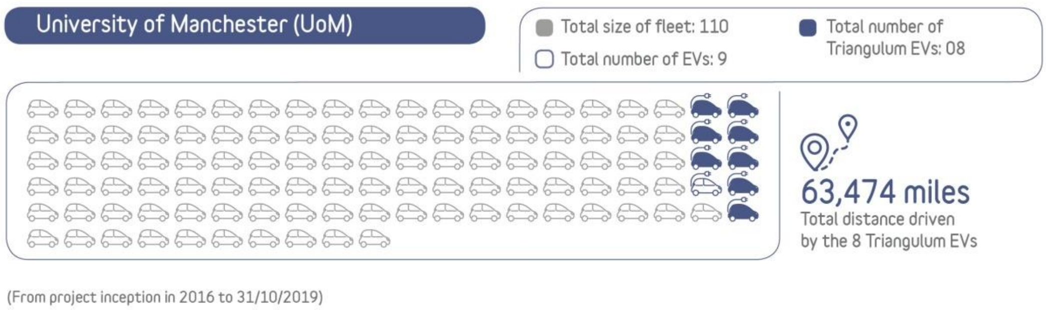

Figure 9: Total UoM fleet vehicles showing proportion of EVs and Triangulum EVs

Whilst the fleet has an electric landscaping vehicle and an eHybrid (BMW 5 Series), Triangulum enabled the first significant step towards electrification.

There is no single person in charge of the fleet. Each department makes its own vehicle choices (dependent on funding and preference). Take up of the EVs has been dependent on departmental engagement.

Trips

The Triangulum vehicles were mainly used by House Services as utility vehicles on regular trips carrying post between sites split across the Oxford Road Corridor.

One is used by the Museum and one by Media Services. They are generally used for carrying equipment between departments and to events and installations.

The e-cargo bike is used by a member of staff for site visits and the student residence manager

Case Study: UoM House Services Van

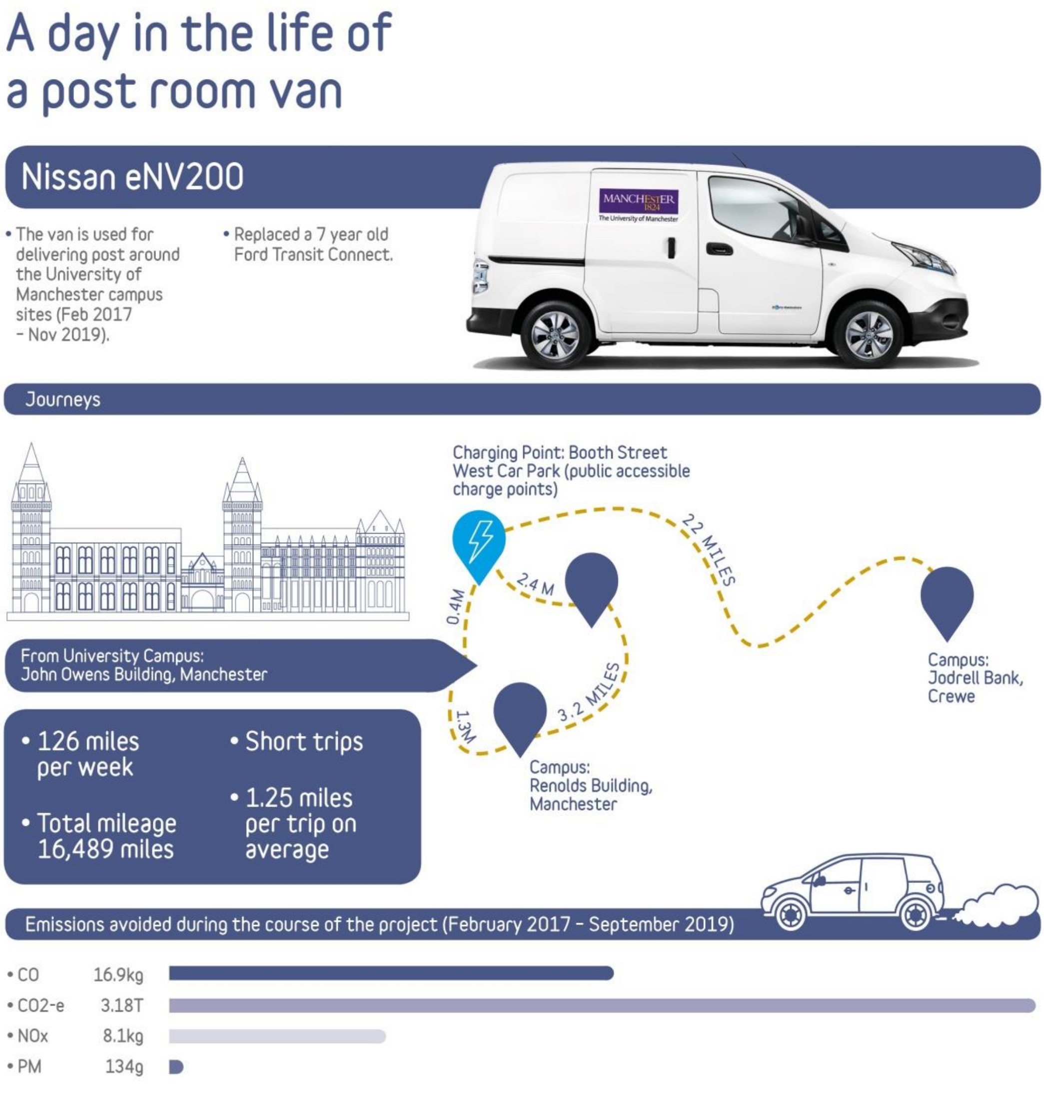

Figure 10: Case study illustration showing driving patterns of a UoM House Services van

Case Study: UoM Facilities E-Cargo Bike

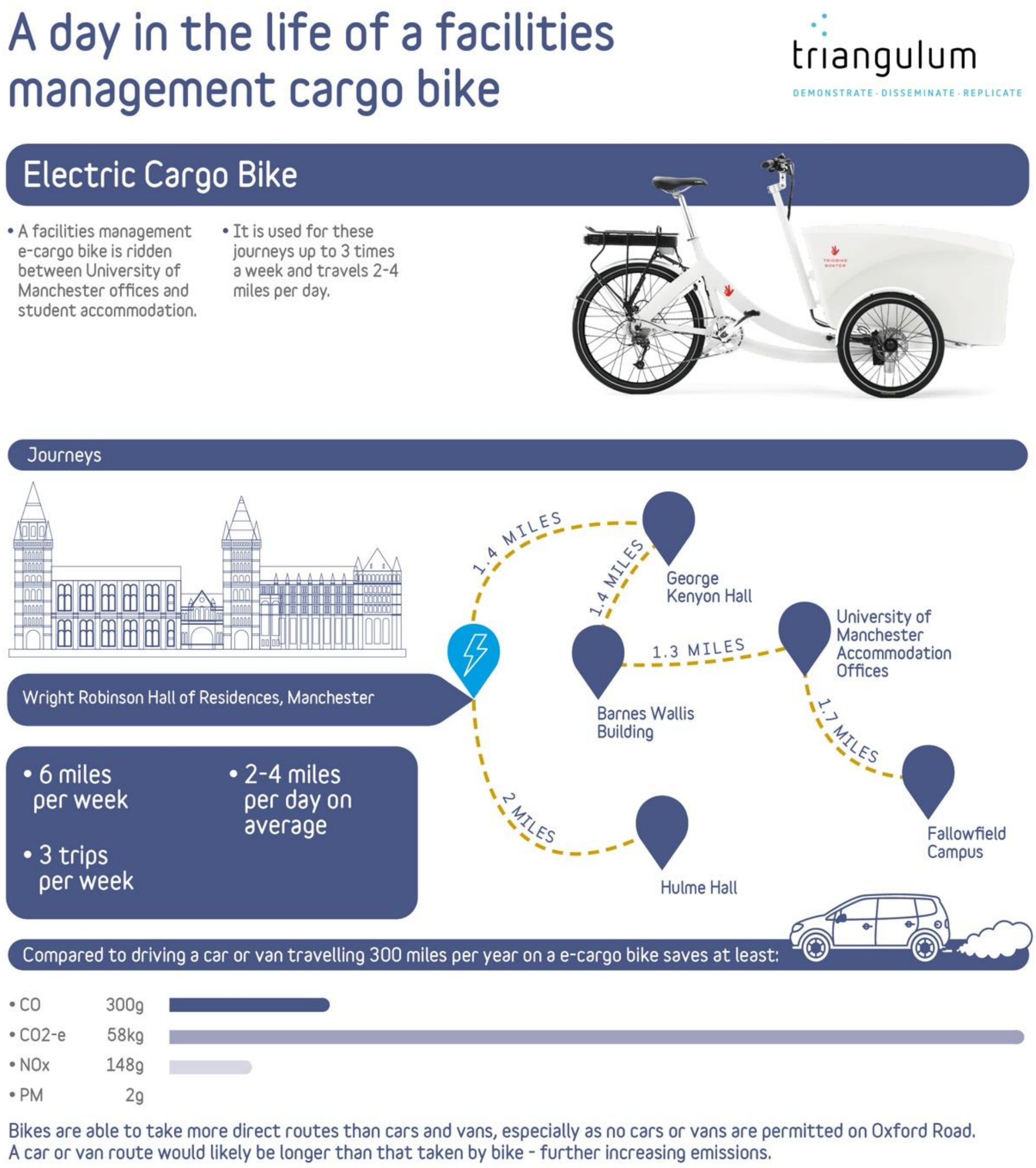

Figure 11: Case study illustration showing driving patterns of the UoM student resident manager e-cargo bike

Impacts

The total mileage of the seven UoM Triangulum vehicles during the project was 63,473 miles.

The House Services vans would cover between 24 and 126 miles per week, with the Media Services van travelling 13 miles per week and the Museum van 46 miles per week.

During the course of the project, the vehicles represented a reduction in CO_2 emissions of 12.03 tonnes and avoided contributing 30.47kg of oxides of nitrogen, 508g of particulate matter and 63.98kg of carbon monoxide to the air.

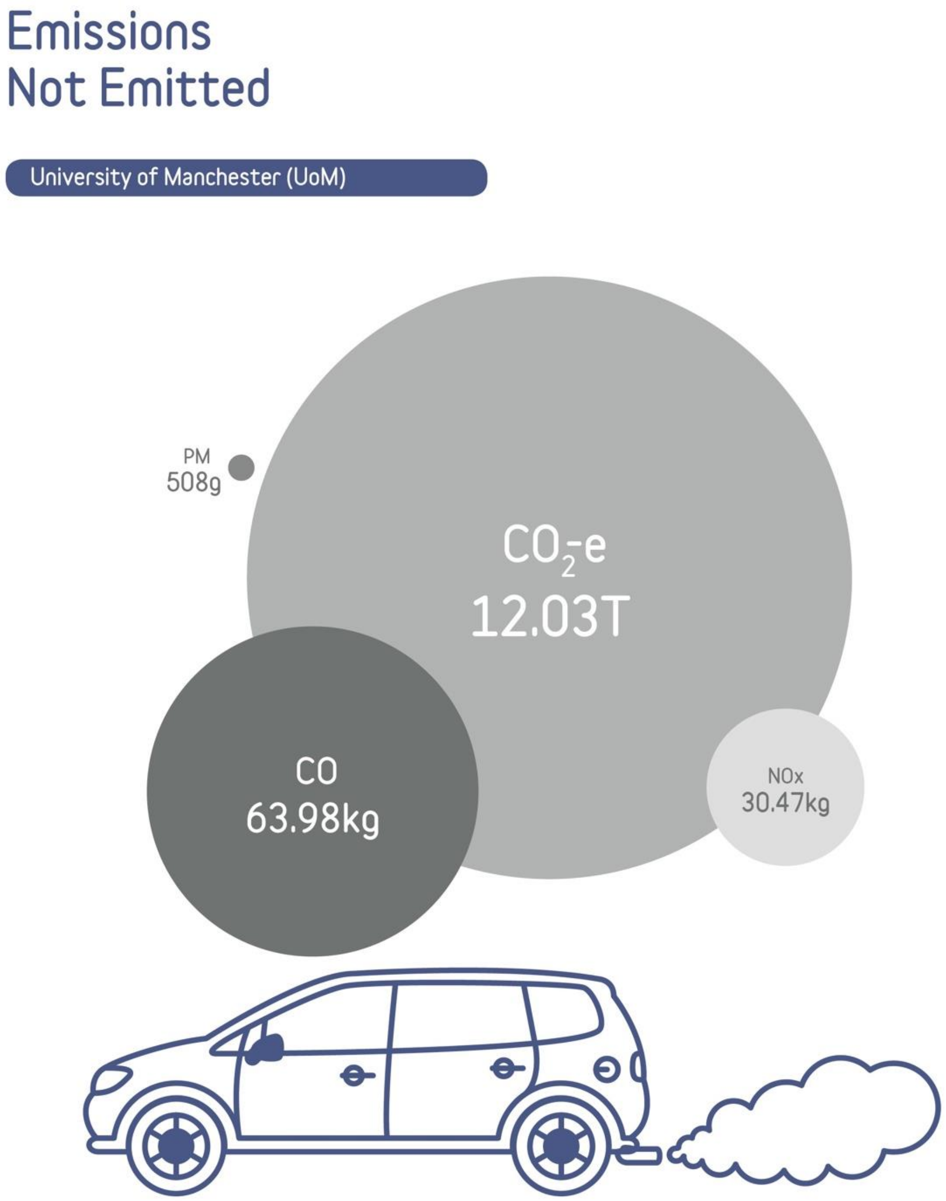

Figure 12: Emissions avoided by the UoM vehicles acquired as part of the Triangulum project

The user feedback around the vehicles was more mixed because their charging was more complicated than the other partners, however it was still very positive:

"Really nice, very easy to drive. Can't knock them. You can concentrate more on road and what's going on around you because they're automatic. Very user friendly."

Behavioural Impact

Summary

The vehicles acquired through the Triangulum Project have been used in very different ways – as utility vehicles used daily by the same group of staff for similar routine journeys at one end of the spectrum and as pool vehicles available to all staff with diverse trip requirements at the other.

This diversity has meant that the evaluation can look at attitudes and behaviours in a range of circumstances.

Attitudes to the EVs to and e-cargo bikes were assessed through a mixture of interviews and surveys to gain a broad sample of users. Surveys were distributed to all the pool car users' at all three organisations so to some extent they are all self-selecting. In addition, 4 UoM post room staff and one other user agreed to complete the survey by interview. In addition, a number of e-cargo bike users were surveyed and interviewed.

Key findings

- People who have used them are positive about EVs.
- Providing pool EVs has improved people's commutes and working lives.

Positive about electric vehicles

The survey asked what people said when they are asked about the EVs. These responses were almost unanimously positive and informative.

40 people gave positive answers, 15 people gave answers which were balanced and informative (e.g. containing a draw back or complication, and 2 people gave negative answers.

Figure 13: Word cloud based on frequency of words used to describe people's experience of driving EVs

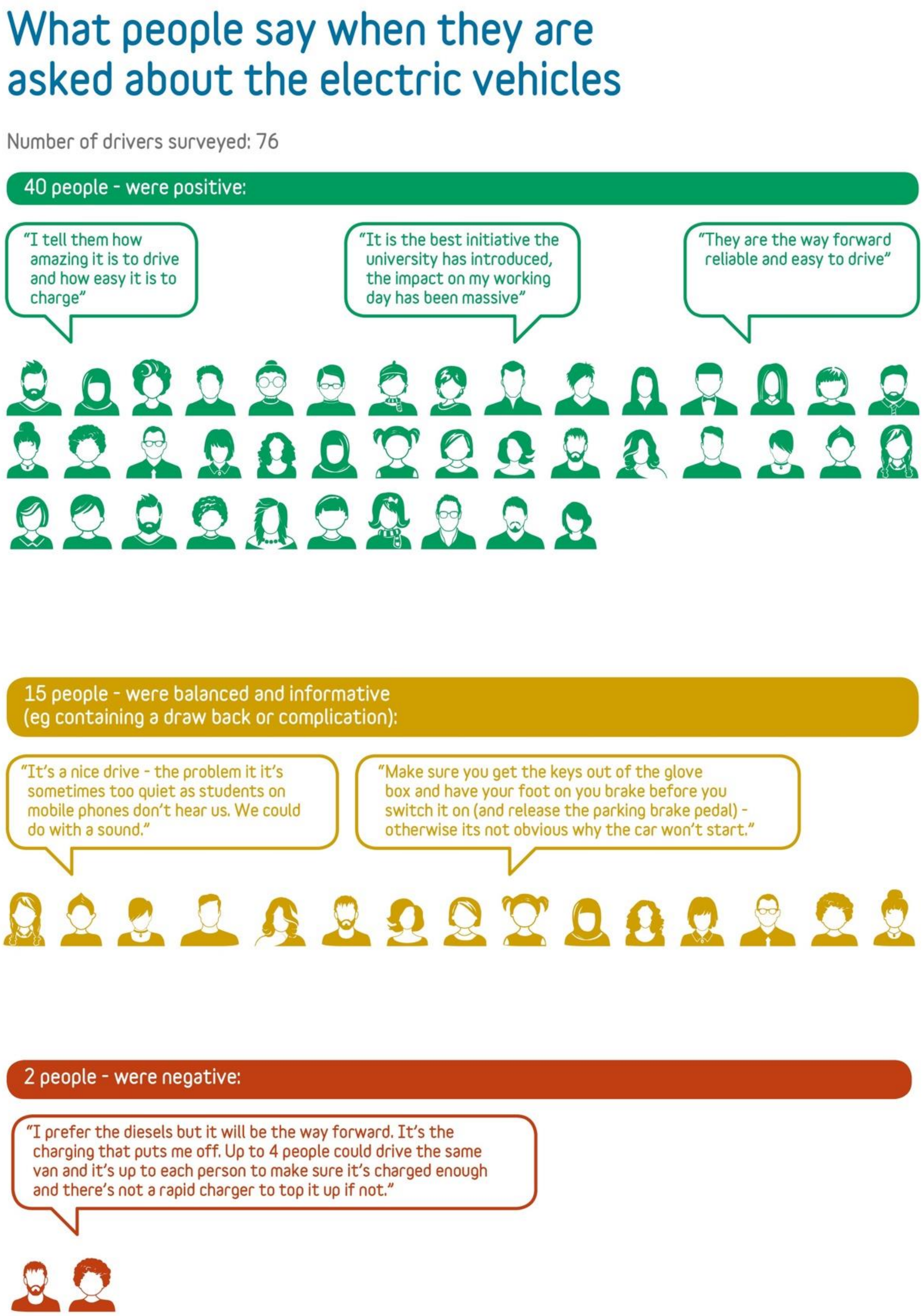

Figure 14: Proportion of positive, neutral and negative comments by people describing their experience of EVs

When asked about their attitudes to getting an electric car:

- 70% of those surveyed ''would recommend' getting an electric car
- An additional 16% would recommend getting an electric car with some conditions or recommendations (eg 'for short trips' or 'if you can afford it')
- 14 % would not recommend getting an electric car at all

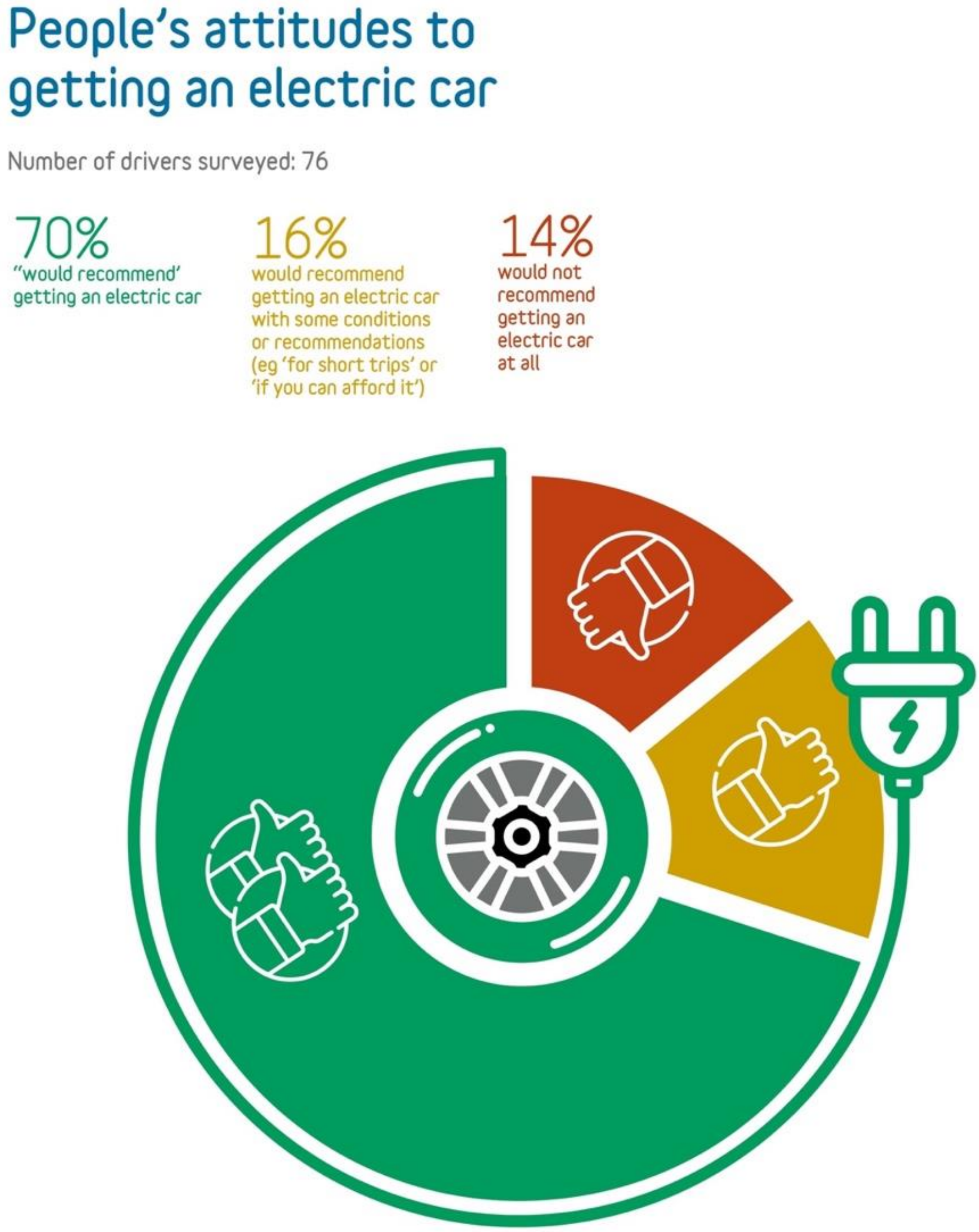

Figure 15: EV users' attitudes to purchasing an EV

This translates into people's future plans:

- 16% of people would consider buying an electric car/van when they next change their car
- 75% would consider buying an electric car or van at some point in the future

- 9% would never consider buying an electric car or van (of which one person - 1.5% - simply does not want any car or van)

Note that one person reported currently owning an electric car and one person stated they had owned one for a while.

General research into UK attitudes to EVs has found that 25% of drivers would buy an electric car in the next 5 years[5].

[5] https://www.bbc.co.uk/news/business-48340202

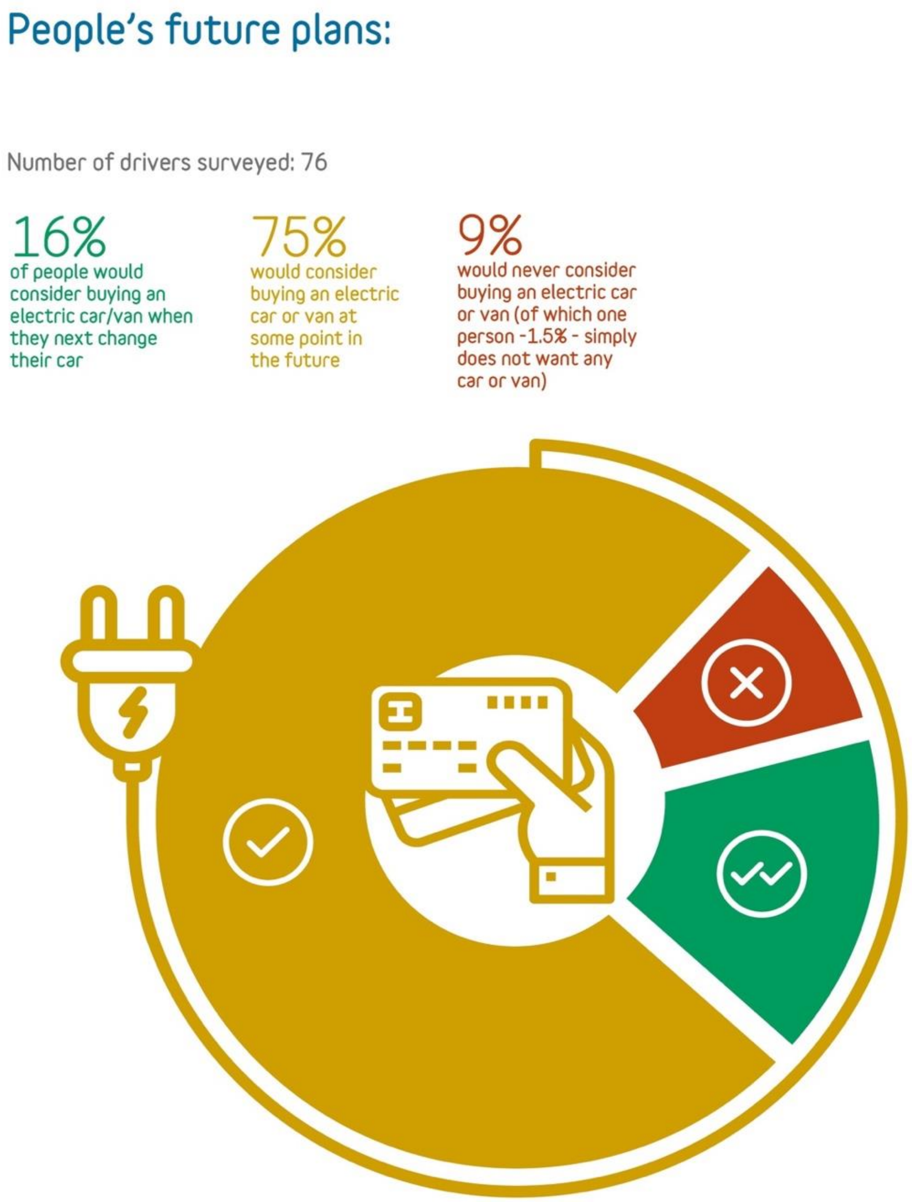

Figure 16: EV users' attitudes to personal EV acquistion and future timescales

Changing commute patterns

At MMU, over 250 staff are registered on the pool car system with over 180 users recorded in 2018. The pool cars have allowed a relatively high number of people to try electric cars.

MMU pool car users were surveyed, and of 50 responses, nine people stated that they were able to change how they travelled to work (18% of those who responded). Of these people, all previously drove to work.

The vehicles are used differently at UoM and MCC and no one felt that they had changed their travel behaviour as a result of the vehicle provision there.

People's comments about the pool scheme included:

> *"Since I know the pool cars are available to use for work events I sold my car."*
>
> *"I use the pool cars for meetings off site mainly. I think there great for getting around the city. I use to drive in to the city but decided to make the commute by train for two reasons a) the pool cars made me think about more sustainable travel b) traffic in and around Manchester is awful."*
>
> *"Means I can use public transport to get to work, then use cars to get to visits."*

As noted in section on the impacts of the MMU Triangulum fleet, it is likely that the indirect emissions avoided by people changing their travel behaviour as a result of the pool car scheme is likely to be many times the direct emissions avoided.

Electric cargo bikes

Trialling e-cargo bikes proved to require a much greater adjustment of behaviour than replacing one ICE vehicle with a very similar electric powered vehicle.

Changing from vans and cars to bikes has the potential to impact on employment conditions (e.g. contracts, terms and conditions) as well as work patterns. It may also require different working environments and dress. A bike needs secure storage and charging facilities, people need changing facilities and lockers for additional weatherproof clothing and potentially showers and drying rooms, for a good experience.

The benefit of an e-cargo bike over a non-electric cargo bike is that it allows the users to carry loads with less effort. In addition, one of the reported benefits from Manchester Bike Hire is that riders can easily set off at a similar pace to a motor vehicle and gain momentum quickly. This is particularly important when transporting heavier loads.

The e-cargo bike work was an opportunity to engage the employees of the three organisations on a voluntary basis rather than via the formal employers' systems. This avoided any issues relating to employment contracts and working conditions.

In order to generate the widest set of use cases as possible and understand more about the best conditions for e-cargo bikes, this element of the project was conceived as a 'bike library' for e-cargo bikes. The hire / "Try before You Buy" scheme bikes were available at no cost to users.

Manchester Bike Hire provided a small fleet of e-cargo bikes to different specifications. The agreement was that Triangulum could have access to four bikes from their fleet at any one time. The benefit of this was that users could trial different models according to their needs and that the project could benefit from newer models. Over the lifetime of the project, the e-cargo bike market has matured with new models coming to market.

Manchester Bike Hire supported the project with try outs and demonstrations at numerous events across the city. For example, Clean Air Day, Manchester Day, events hosted by Transport for Greater Manchester (TfGM) and the annual cycle event facilitated by Oxford Road Corridor. The three organisations also publicised availability to their staff.

The e-cargo bikes created an opportunity for new users to be exposed to a different way of travelling around the city and also to raise the profile of e-cargo bikes as an option.

Individuals who tried the bikes briefly at events were not counted (often they were just interested individuals etc.). There were over 30 enquiries and 20 formal trials resulting in 2,876 days of e-cargo bike hire.

A notable success is illustrated in Figure 17 with the company Lunchbrakes. This is a small business who moved from a domestic trailer for their deliveries to a bespoke trailer. This has allowed them to expand their operation. They have also partnered with Last Mile Logistics (a sister company of MBH) for deliveries. Previously they hired their own riders.

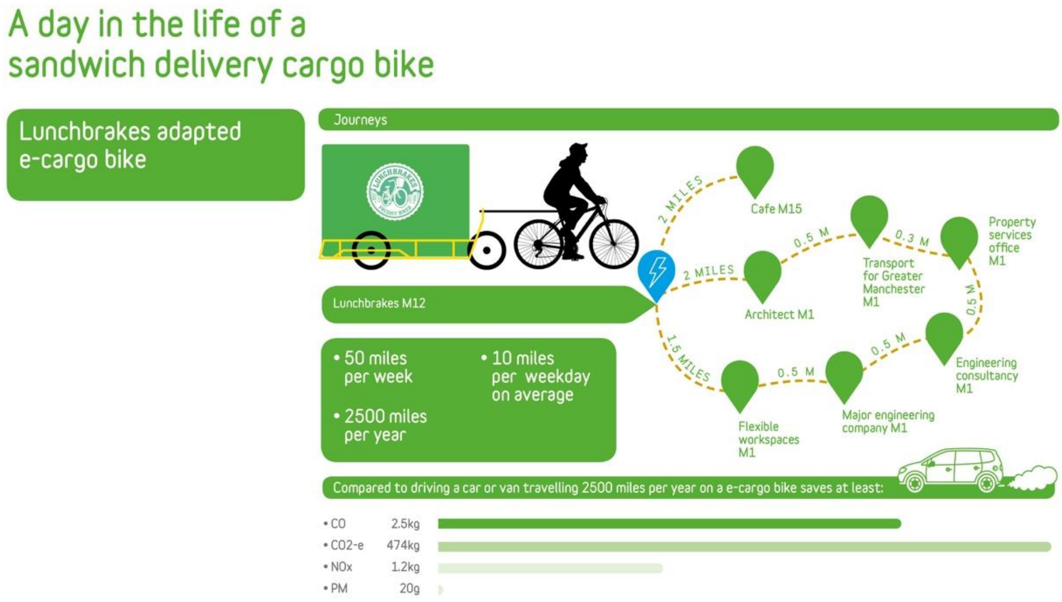

Figure 17: Case study illustration showing riding pattern of the Lunchbrakes sandwich delivery e-cargo bike

The 20 formal trial users were surveyed and 7 responded. There were some issues with contacting users of the scheme – emails were no longer current, people had moved home or employment, businesses were no longer operating, all of which contributed to the low response rate.

Of the 7 responses (people could choose more than one use in personal/business and work travel):

- 2 respondents used them for personal travel
- 5 used them for business purposes
- 1 used it for work

In terms of satisfaction:

- 3 people found the e-cargo bikes useful for their businesses
- 1 person found it useful for their work
- 1 person found it useful for personal travel

Ongoing use of e-cargo bikes:

- 1 business bought an e-cargo bike
- 1 person bought an e-cargo bike for personal use (commuting, carrying children etc.)
- 1 person obtained an e-cargo bike as a work vehicle

An eighth person who has tried and obtained an e-cargo bike as a work vehicle was interviewed and was very happy with it. The interview is the basis of the case study shown in Figure 11.

There were several factors for those who did not continue to use the bikes, including the cost of purchase and storage as well as the rider experience.

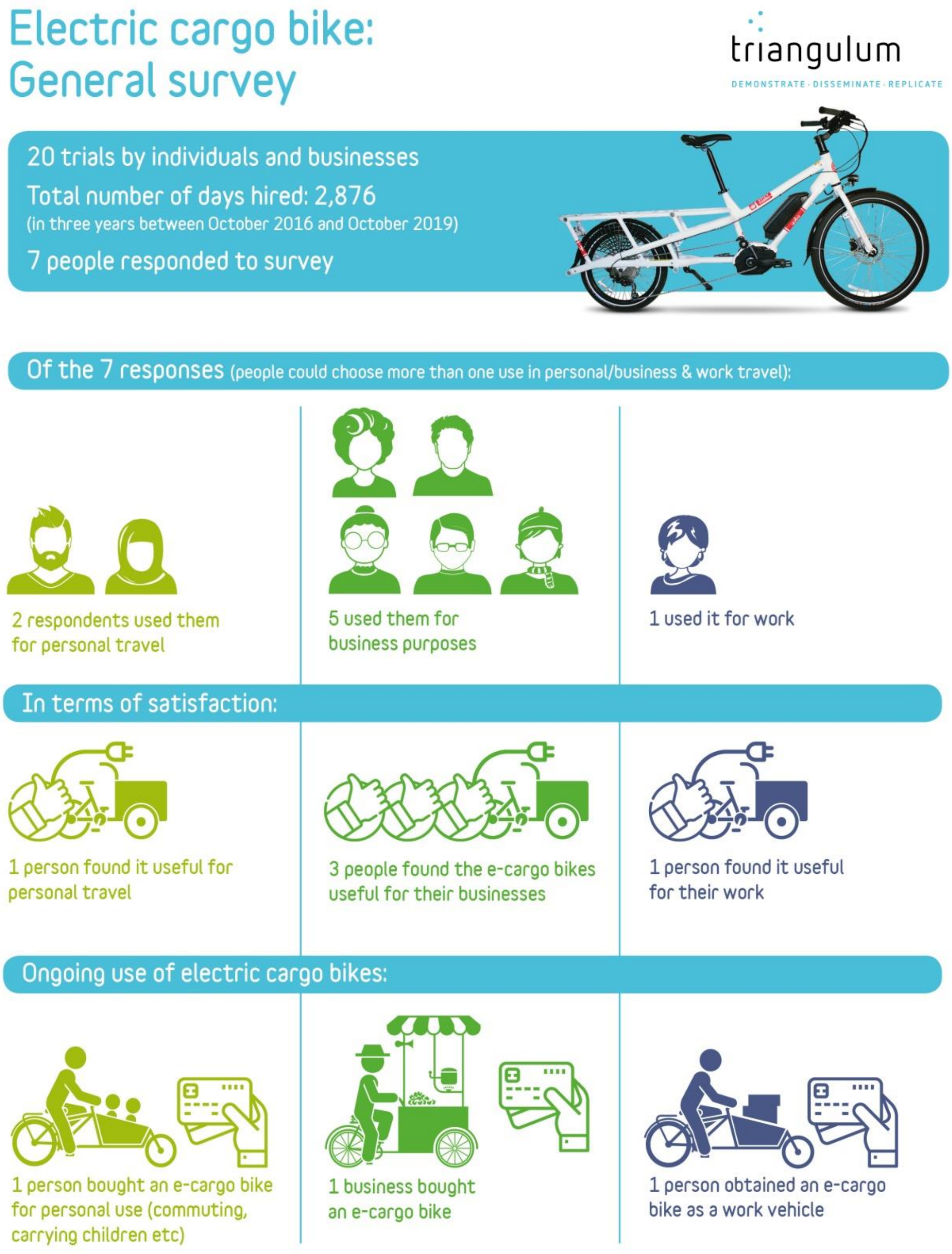

Figure 18: E-cargo bike trial participants' experience of e-cargo bikes

Emergent themes

A number of themes have emerged in the course of the evaluation surrounding the uptake and use of EVs and e-cargo bikes.

Issues such as staff travel policies, parking policies and the structures around fleet management had implications for the successful deployment and optimisation of the fleet.

With data it is also possible to evaluate the longer term performance of the EVs, and the cost differential to demonstrate how this reduces over time.

Whilst this is all 'early stage' technology it is anticipated that real cost differentials over time will be negligible (or favour EVs).

These themes are explored below.

Fleet management

There were implications for budgets and accounting practices both when vehicles were purchased and with respect to ongoing costs switching from diesel and petrol fleet to electric fleet.

The most important element for successful implementation was a dedicated fleet manager with oversight of the entire fleet. This enabled vehicles to be pooled between departments reducing the number required.

The impact of a dedicated fleet manager can be seen in the metrics.

The MMU fleet manager is answerable to senior management on delivery of the organisation's environmental sustainability objectives. This oversight function allows those objectives to be prioritised and the fleet optimised in line with them. MCC demonstrates a similar way of working.

The number of fleet vehicles per member of staff at MMU is half that of UoM. This reflects the role of the dedicated fleet manager optimising the fleet between departments rather than each department purchasing their own fleet without pooling their use of vehicles.

A smaller more efficient fleet reduces both capital expenditure and running costs. It also has implications for parking and garage space where they are at a premium.

In addition, whilst EVs are more expensive to purchase initially, fleet optimisation has allowed MMU to manage a lean fleet, reducing the need for capital expenditure and increasing the proportion of EVs to 41% (compared with 8% at UoM).

Table 1: Fleet Metrics MMU and UoM

MMU model: All vehicles managed by a dedicated fleet manager	
MMU is a large university with 38,000 undergraduate and postgraduate students. There are around 4,400 staff employed by the university.	
Total fleet during project:	24 vehicles
Space requirement for fleet:	$420m^2$[6]
Total parking provision:	700 spaces
Staff to parking ratio:	6.3 staff : 1 parking space
Staff to fleet ratio:	183.3 staff : 1 fleet vehicle
Percentage of EVs in fleet:	41%
UoM model: Fleet purchase and management devolved to teams	
UoM is slightly larger than MMU with over 40,000 students and 10,400 staff.	
Total fleet during project:	110 vehicles
Space requirement for fleet:	$1,927m^2$
Total parking provision:	3,000 spaces
Staff to parking spaces ratio:	3.5 staff : 1 parking space
Staff to fleet ratio:	94.5 : 1 fleet vehicle
Percentage of EVs in fleet:	8%

Vehicle purchase and leasing

The difference between vehicle purchasing and leasing highlighted the importance of dedicated fleet management.

The MMU fleet manager worked with the university's accounts team to calculate the most efficient means of acquiring fleet for the university as a whole. For the

[6] Indicative estimate based on British Parking Association recommended bay size and circulation guidance

Triangulum vehicles this was outright purchase due to the cash position of the university, however in other financial years that might have been different.

The MCC fleet manager similarly works with individual departments to identify the best vehicle for the purpose with a view to ensuring best value and also with consideration to the organisations carbon reduction targets.

In contrast, the vehicles were acquired by teams at UoM by teams with much broader job descriptions and without expertise in leasing and vehicle acquisition. In addition, staff changed several times during the course of the project. Unfortunately, the initial six Nissan eNV200s acquired by lease were returned towards the close of the project and the department returned to ICE vehicles.

Costing and accounting for the Triangulum programme vehicles

All three organisations managed their costing and accounting differently, and the funding from the Triangulum project was used in different ways in order to offset the additional costs of EVs. The calculations below assume no funding (other than central government EV grants) in order to calculate the relative costs of EVs and ICEs. In the course of the project, the partners either did not make savings, were not focusing on savings or found them difficult to account for. New accounting practices need to be considered by organisations as they move to EV fleets.

UoM

Individual department hold their own budgets for their vehicles and this meant they had oversight of the costs and benefits. For the post room team, the grant from Triangulum and UK's government electric vehicle grant meant that the monthly lease costs of the vehicles were low (£150 per month). The vehicles were charged at free charge points so running costs were minimal. There was also virtually no maintenance required.

Whilst it is hard to calculate figures for the diesel saved (short, frequent low speed trips can have relatively high fuel consumption) from an ongoing cost point of view the team would have preferred to continue with EVs.

MCC

Triangulum project funded the difference between leasing diesel vehicles and EVs meaning the EV acquisition was cost neutral. Once acquired the costs of running the EVs are low (all maintenance is included in the lease costs) and electricity is less expensive than other fuel. Whilst the fleet manager felt that the vehicles had been inexpensive to run, the comparison between EVs and diesel vehicles (with fuel records and servicing) was still being assessed.

MMU

The pool cars are provided centrally by the university (i.e. not allocated to particular department) as part of the environmental strategy to assist the university in reducing its carbon emissions and as such are not costed to departments.

It is possible to calculate cost of electricity for the vehicles (a minimal £538 for the two vehicles for the duration of the project) however this absorbed by central costs. The direct impact on departments is that they no longer pay mileage allowances to staff.

The MMU cars were provided to directly replace grey fleet usage (staff using their own vehicles in the course of their work) as this was putting pressure on the limited parking available to staff. The project costs of replacing grey fleet use with pool cars was higher than equivalent mileage because of vehicle acquisition and the running costs of telematics (see Table 2). Where parking is a constrained resource this is the only option.

Table 2: MMU Pool Car Costs

Costs	
Vehicle purchase (2 x Nissan Leaf)	£41,940
Electricity cost (12p /kWh)	£538
Enterprise key management (3yrs)	£10,800
Total	£53,278
Savings	
Distance miles	32,533
45p per mile	£14,640
Balance	-£38,638

Calculating the costs of EVs – fleet management issues

EVs have a higher capital / vehicle acquisition costs but lower running costs. All organisations face a challenge to reflect this in their budget cycles and accounting practices.

Good practice in fleet management tends to view inflexible long term assets – owning ICE vehicles – as sub-optimal because they are insufficiently flexible to meet the needs of the organisation and keep costs down. This has generally been in line with sustainability metrics as it has enabled organisations to upgrade vehicles regularly and move to higher emission standard vehicles promptly.

For instance, the MCC fleet is managed by a dedicated manager who is responsible for a supply framework contract. He has an in-depth knowledge of the fleet for the whole organisation as well as relationships with suppliers to ensure best value.

The manager manages leases via a supplier's framework contract which draws on existing relationships as well established terms and conditions for the lease. This enables vehicles to be leased for as long or short a period as needed, aimed at the smallest fleet to meet needs.

Whilst this has worked well for the process of upgrading parts of the fleet to electric (and also for disposing of older legacy vehicles with high emissions), an evaluation of electric vehicle costs indicate that the higher capital / lower running cost scenario may favour a different model.

The tables show use actual costs and usage of the 2016 MMU Triangulum Nissan Leafs. These were purchased outright, so their costs can be amortised over their actual lives. If that lifecycle is only three years, the higher capital outlay of EV is not completely balanced by reduced fuel costs compared to an ICE vehicle. Table 3 shows that the costs are not yet bridged over 3 years because of the difference in price between the Leaf and the smallest and cheapest ICE vehicles.

However, over a longer timescale the differences fall. The tables project costs over 5 and 8 years to give an indication of the potential. These timescales have been used as MMU has some 5 year old EVs which have shown little or no deterioration in battery life. Current products have an 8 year or 100,000 mile battery capacity loss warranty which indicates that an 8 year life cycle is realistic (and possibly beyond).

Comparing the Nissan Leaf with the slightly larger Nissan Juke (rather than the slightly smaller Nissan Micra) and the differences reach parity after 5 years and favour the EV at 8 years.

Future costs of fuel and other costs such as clean air zone emission charges have not been projected – these could have major cost implications in future which could increase the costs of running the ICE vehicles.

Nissan Leaf (2016 model) vs Nissan Micra ICE 2016-19

Table 3: Annual costs of Nissan Leaf vs Nissan Micra over 3 years

Over 3 years (project life)			
Vehicle purchase (2 x Nissan Leaf) (actual)	£41,940	Vehicle purchase (2 x Nissan Micra) (website price guide £14,190)	£28,380
Electricity (actual @ 12p/kWh)	£538	Fuel (based on 48mpg @ £1.199 per litre)	£3,694
Staff mileage (actual)	32,533	Staff mileage (assumed)	32,533
Total	£42,478	Total	£32,074
Additional cost of EVs: £10,404 over 3 years or £3,468 per year			

Table 4: Annual costs of Nissan Leaf vs Nissan Micra over 5 years

Over 5 years			
Vehicle purchase (2 x Nissan Leaf) (actual)	£41,940	Vehicle purchase (2 x Nissan Micra) (website price guide)	£28,380
Electricity (based on 12p/kWh)	£972	Fuel (based on 48mpg @ £1.199 per litre)	£6,157
Staff mileage (projected - linear))	54,222	Staff mileage (projected - linear))	54,222
Total	£42,912	Total	£34,537
Additional cost of EVs: £8,375 over 5 years or £1,675 per year			

Table 5: Annual cost of Nissan Leaf vs Nissan Micra over 8 years

Over 8 years			
Vehicle purchase (2 x Nissan Leaf) (actual)	£41,940	Vehicle purchase (2 x Nissan Micra) (website price guide)	£28,380
Electricity (based on 12p/kWh)	£1,555	Fuel (based on 48mpg @ £1.199 per litre)	£9,851
Staff mileage (projected - linear)	86,755	Staff mileage (projected - linear)	86,755
Total	£43,495	Total	£38,231
Additional cost of EVs: £5,264 over 8 years or £658 per year			

If the Nissan Leaf is compared with a bottom of the range Nissan Juke (£17,395) rather than a bottom of the range Nissan Micra (£14,190) the Nissan Juke costs exceed those of the Nissan Leaf over 8 years.

Table 6: Annual cost of Nissan Leaf vs Nissan Juke over 3 years

Over 3 years (project life)			
Vehicle purchase (2 x Nissan Leaf) (actual)	£41,940	Vehicle purchase (2 x Nissan Juke) (website price guide £17,395)	£34,790
Electricity (actual @ 12p/kWh)	£538	Fuel (based on 40 mpg @ £1.199 per litre)	£4,433
Staff mileage (actual)	32,533	Staff mileage (assumed)	32,533
Total	£42,478	Total	£39,223
Additional cost of EVs: £3,255 over 3 years or £1,085 per year			

Table 7: Annual cost of Nissan Leaf vs Nissan Juke over 5 years

Over 5 years			
Vehicle purchase (2 x Nissan Leaf) (actual)	£41,940	Vehicle purchase (2 x Nissan Juke) (website price guide £17,395)	£34,790
Electricity (based on 12p/kWh)	£972	Fuel (based on 40 mpg @ £1.199 per litre)	£7,389
Staff mileage (projected - linear))	54,222	Staff mileage (projected - linear))	54,222
Total	£42,912	Total	£42,179
Additional cost of EVs: £733 over 5 years or £147 per year			

Table 8: Annual cost of Nissan Leaf vs Nissan Juke over 8 years

Over 8 years			
Vehicle purchase (2 x Nissan Leaf) (actual)	£41,940	Vehicle purchase (2 x Nissan Juke) (website price guide £17,395)	£34,790
Electricity (based on 12p/kWh)	£1,555	Fuel (based on 40mpg @ £1.199 per litre)	£11,823
Staff mileage (projected - linear)	86,755	Staff mileage (projected - linear)	86,755
Total	£43,495	Total	£46,613
Additional cost of EVs: -£3,118 over 8 years or a saving of £390 per year			

These figures assume that fuel and other costs remain the same to give indicative costs. Servicing costs are not included. Over a longer timescale these would be expected to diverge in favour of the EVs as they have fewer moving parts and consumables. Brake pads are replaced less frequently because EVs largely regenerate power in order to brake rather than through the application of pressure through pads.

As EV prices fall this cost differential is likely to decrease.

Although EV range is likely to go up as new models are introduced, there is less imperative to move onto new models for air quality / CO_2 emissions. Indeed, the CO_2 sunk into vehicle manufacture implies that the most sustainable outcome is that the vehicles should be charged with renewable energy and run until failure to minimise its carbon footprint.

The implications are that fleet managers should consider the whole life costs and sustainability when switching to EV before deciding on their acquisition model.

Interestingly, it may well be that the leasing' option is less efficient for organisations. Whilst these deals can seem attractive it appears to be difficult to make lifetime savings by acquiring EVs through current leasing deals. For example see Table 9.

Table 9: Lease costs of Nissan NV250 vs Nissan eNV200

ICE van:			
Nissan NV250 (36 months, annual mileage 10,000)[7]	£16,490	£1,194 initial	£199pm + vat
Electric van:			
Nissan eNV200 (36 months, annual mileage 10,000)[8]	£20,005	£1,194 initial	£319 + vat

The electric Nissan costs an additional £1,440 per year. However, on a restricted mileage it is not possible to save that in fuel savings:

Fuel costs for annual mileage of 10,000 miles:

Diesel @ 48mpg & £1.199 per litre	£1,135
Electricity @ 12p/kW & 330wh/mile	£394
Fuel saving	£741

For vehicles purchased on lease the annual savings will be identical each year – and the vehicle is due to be returned at the end of the 3 year term. This implies that at current pricing and business models the EV vans will be around £700 per year more to run than their ICE equivalent. Servicing is included in both leases (so any gains related to reduced servicing costs are gained by the manufacturer/leasing company).

Other savings may be made where EVs do not attract charges in clean air zones, however on fuel savings alone leased EVs have not yet reached parity with ICEs.

Batteries and vehicle life

Battery longevity is cited as an issue for concern (at least in the media) but it is only with real life use that we can see how well battery capacity holds up over time.

Initial predictions of rapid decline and vehicles being rendered useless in 3 years because their batteries no longer hold sufficient charge to complete their journey patterns have been unfulfilled.

It is hard to predict the life cycles of these vehicles; however, present indications are that they will be much longer than were originally anticipated at the outset of the

[7] Nissan website 2020 prices : https://www.nissan.co.uk/vehicles/new-vehicles/nv250.html

[8] Nissan website 2020 prices: https://www.nissan.co.uk/vehicles/new-vehicles/e-nv200.html

programme. Typically, vehicles coming to market in 2020 have 8 year battery warranties.

The longest serving vehicles in the Triangulum fleet are the two Nissan Leafs acquired by MMU in August 2016. These have had annual services at Nissan. The three services have shown no degradation of the battery.

This is despite the use pattern not following optimal battery care guidelines. Due to the number of users and the requirement for each user to have a fully charged vehicle the cars are put on charge at the end of every session. Nissan recommends that batteries are largely discharged before recharging. Thus far this has not had any impact on the battery capacity.

Parking and travel policies

The interaction between staff parking and fleet parking (and charging) impacted how EVs could be deployed. Where parking policies were not within the control of those managing fleets, it is more difficult. All parking at MCC locations was in council owned garages or land and for this reason no case study is included.

Case Study: Manchester Metropolitan University

MMU has limited staff parking with only 700 spaces for its 4000+ staff. A review of parking permits led to the creation of a policy that prioritised permits for those who needed them most on grounds of mobility, caring responsibilities or the absence of alternative transport. Only once places are allocated to these priority groups are permits are discretionary permits made available. The allocation of parking permits is reviewed annually and users do have no automatic right to renewal.

The parking review also showed that a number of people were driving to work solely in order to be able to use their cars in the course of their work, adding pressure on the limited car parking. To enable those people to change their mode of travel, pool cars were provided. These can be booked and used by any member of staff. The Triangulum Nissan Leafs became part of this pool car scheme. They were allocated their own charging bays (where they were parked between trips). The charge points were paid for by the Triangulum project meaning they were dedicated to the pool cars and enabled the cars to be fully charged at the beginning of each day and to charge between uses during the day time.

Pool car user:

> *"It's the best initiative the university has introduced, the impact on my working day has been massive."*

This scheme is user friendly and has met with a great deal of support. There was very little concern about charging from staff surveyed about these vehicles. The vehicles have relatively high mileages and utilisation rates, implying that this has worked well.

Case Study: University of Manchester

This parking policy can be contrasted with that at MMU. The UoM system operates on a 'first come, first served' basis, with currently 780 people on the waiting list for parking permits. The available capacity is 3,800 parking spaces including allocations to tenants (as part of their lease), blue badge holder spaces, contractors and visitors. Staff purchase parking permits. These are allocated on the basis of 1.3 permits per available space. Staff driving low emission vehicles qualify for discounts.

An additional complication for the deployment of EVs is that the charge points available are situated within the University's car parks and were specified as publicly accessible when they were commissioned. There were no additional charge points scoped (either by the University or for the Triangulum project) for fleet vehicles.

The consequence is that staff who drive EVs and who have parking permits can use the charge points if they are available. According to the annual staff survey, 300 staff reported they drive EVs. Hence staff cars are regularly parked in charging bays, charging all day. As a consequence, people whose jobs involve EVs are competing with those who drive to work in order to charge their cars.

This has been addressed to a degree by the team waiting for staff to leave at the end of the working day and then relocating all the House Services vans to charge points to charge overnight. This is however an additional burden on the team in terms of time and a source of anxiety.

Postroom staff quote:

> *"I prefer the diesels but it will be the way forward. It's the charging that puts me off. Up to 4 people could drive the same van and it's up to each person to make sure it's charged enough and there's not a rapid charger to top it up if not."*

The impact of parking and travel policies

A lack of staff travel and parking policies have made the use of EVs by the teams more labour intensive than ICE vehicles.

In contrast, where staff travel and parking policies are aligned with environmental objectives – explicitly to reduce driving and switch to sustainable travel – this supports the deployment of the EVs. The use of these vehicles has proved easier, been welcomed by staff and been more efficient. As a result, the impact of the vehicles is increased.

Data collection

Data collection was more difficult than expected at the outset of the project. Although systems were available, they proved to be less robust than expected and data collection was time intensive. This had to be addressed to get proper data with which to evaluate the impact of the project.

MMU and UoM acquired Nissan vehicles with the CarWings upgrade. CarWings is a vehicle telematics service offered by Nissan. However, data had to be downloaded manually from each vehicle via a USB connection and it quickly became clear that the system is aimed at the domestic user rather than fleet.

To address this, MMU procured Fleetcarma on behalf of themselves and UoM. Fleetcarma is a fleet vehicle telematics system that allows mileage and charging events to be recorded. It is possible to do this without live GPS location tracking – full live vehicle tracking proved to be an issue for staff and outside the scope of current contracts (see chapter on working practices). MCC's fleet all have tracking as standard.

In fleet management it is important to be able to see how often vehicles are used and what kinds of trips are being made (multiple short vs a smaller number of long trips), in order to evaluate and optimise the fleet. For instance, it could show potential for sharing vehicles between teams (depending on location).

The learning curve for collecting data about the e-cargo bikes was even steeper. In order to measure mileage, various electronic tracking options were attempted. The initial attempts using an AutoTrip software subscription and self-soldered add on units failed due to water ingress and vulnerability to damage.

During the course of the project, however, more options have become available.

A Linka system was fitted to the bike at UoM used by the residence manager. The through the wheel locking system provides a shared use facility via app based remote locking. The Linka is weather proof with a battery life of 16 months. The tracking facility uses a SIM with associated costs. There is an added benefit in that the bike can be located at any time.

This system enabled trip lengths and patterns to be sampled for the case studies. Over time it could provide usage data to calculate carbon and air quality impacts, however, only a small sample was available by the end of the project.

Electric charging infrastructure experience and impacts

Charging experiences

The vehicles deployed as part of the Triangulum project were charged in different ways:

- MMU Nissan Leafs used dedicated 7kW on-street charge points;
- MCC vans are charged using 3 pin (13A) supply in garages or on site and their Leaf on a dedicated charge point connected to a solar panel (this exports to the grid when vehicles are not charging);
- UoM uses 7 kW public charge points on the university campus car parks.

Interestingly, MCC users reported no conflicts between use patterns and charging with vans using 13A charge points (max 2kW per hour). Although this is the slowest charge rate – taking 25 hours to fill a 50 kW battery from empty – leaving the vehicle on charge overnight was perfectly sufficient. The vehicles in question were used well within their maximum range and were generally charged overnight in garages for the 16 non-working hours (enabling a 32kW charge). This returned them to fully charged in that time.

Users of the Nissan Leafs with dedicated fast (7kW) charge points also reported no issues with charging the vehicles or levels of charge at the dedicated charge points.

Those making longer trips had some frustrations with the charging network and having to set up various accounts with different providers and reclaim costs as expenses.

Fleet manager:

> *"There should be a fuelcard for electric vehicles"*

The most conflict and issues reported with charging was with those vehicles which were in constant circulation and had to use fast (7-22kW) public charge points. Experience proved they were regularly busy. These vehicles did not have access to rapid (50kW) charge points for 'top ups'. As a result, being unable to access the slower chargers could seriously affect subsequent work tasks.

The usage patterns of these vehicles meant that they needed to be at full charge at the beginning of the day to complete their workload. Ensuring that they could be parked at a charger overnight could be unpredictable due to competition from the other campus staff.

Installing chargers

It was recognised by all partners that dedicated charge points would be good practice and make the use of the EVs easier.

This was only achieved for the MMU Nissan Leaf cars and the MCC Environmental Health team's Nissan Leaf. The former was made possible by Triangulum funding and the latter took advantage of an installation as part of a different programme.

The reasons for not installing charge points included:

- Lack of electrical network capacity – some sites identified proved not to have available capacity.
- Facilities in flux – where facilities are marked for potential closure it did not make sense to invest in vehicle charging infrastructure.
- Dedicating space – where policies do not provide kerb or parking space that can be dedicated to chargers.
- Decisions still to be made on an organisational wide infrastructure meaning that more specific requests were in abeyance.

Smart charging

There was no direct connection between the installed chargers and the energy management elements of the Triangulum project.

This was largely a matter of timing with chargers being installed ahead of the availability of smart management technology. The developments in charger technology have only become available since the initial charge points were installed. Vehicle to Grid (VtoG) charging is still in development and some chargers can be configured to charge responsively (e.g. to solar generation or in response to pricing triggers).

Technology is developing so rapidly that obsolescence can occur in short cycles. As systems develop, however, connectivity has become more sophisticated and standards for smart chargers will become more established. In addition, as chargers become more sophisticated, software updates may mean that it will be possible to reconfigure them remotely in future.

Working conditions and practices

There are two sets of complications relating to changing vehicle options for staff working for the three partner organisations – changing vehicle types and the collection of trip data.

Type of vehicle

Moving from an ICE car or van to an EV or e-cargo bike may not be specified in contracts of employment.

Some changes in working practice were highlighted but for EVs much is very similar as driving ICE vehicles. Issues were presented such as the lack of an equivalent to a fuel card for EVs. This is wider issue for all EVs, drivers and fleets at present and adds personal admin as people needed to set up personal accounts with charge providers then claim back the costs of charging.

Training was provided for all EV drivers – whilst fleet managers often spent some time raising awareness of the EVs, the actual training was generally reported as very straightforward and quick. Fleet managers identified that trained users also engage in peer-to-peer training.

For e-cargo bike users the programme has relied on people volunteering to change their working practices.

At present there is no value put on the well being implications of offering active travel options for people to complete their jobs. However, staff who use the e-cargo bikes are enthusiastic about them and the health benefits of activity are well recognised. Training was provided by Manchester Bike Hire. The standard employers' liabilities exist for e-cargo bikes as for all vehicles.

Data collection

Data collection is a more challenging issue as human resource management issues are affected by the perception of connected vehicles and data collection.

The issue for fleet management is that data is essential for optimising fleet use and ensuring that vehicle assets are maximally utilised – particularly as EV assets represent higher capital expenditure. Without data it is hard for fleet managers to assess which vehicles are used optimally and where lightly-used vehicles could be shared between teams. Live state of charge data is crucial for efficient fleet use.

Connected vehicle data is also increasingly used to ensure the health and safety of staff driving as part of their work (monitoring speeds, smooth driving, sufficient breaks, links to dashcams etc) in commercial fleet management. It also is regarded as good practice for fleet insurance (for instance it can reduce premiums) and to protect staff in the event of any incidents.

Electric fleet is increasingly managed through connected vehicles (ensuring batteries are charged before dispatch for instance) and vehicles are now being produced with connectivity factory fitted (Teslas for instance).

Partners will need to include data collection within accepted working practices in future to enable a shift to electric vehicles. Whilst this is at an additional cost, it should be considered an investment in terms of fleet management.

Lessons and Recommendations

General

A whole organisation approach to environmental sustainability enables the greatest impacts. Maximum value can be achieved through a comprehensive approach encompassing staff travel and parking policies, charging infrastructure and fleet management.

Electric vehicles

A dedicated fleet manager provides a good oversight to optimise fleet use between departments and also focus on sustainable travel, e-cargo bikes, and parking requirements. Utilising a framework approach to procurement also provides for good contract terms and conditions.

Vehicle sharing across the organisation increases utilisation and efficiency. An overall reduction in fleet numbers enables increased adoption of EVs and reduces the space required for parking. It also allows for savings from staff car allowance payments.

Dedicated parking and charging is essential for successful deployment of EVs.

Contracts of employment and working practices need to reflect a move to more sustainable vehicle types and modern fleet management to:

- Provide training and information around EVs and e-cargo bikes to support staff using vehicles that are new to them
- Ensure that people are using the correct vehicle or travel options for the job – including active travel options like e-cargo bikes.
- Enable the use of connected vehicles and data collection from vehicles provided for work purposes (both to assist fleet management and support employers' duty of care).
- Increase active travel within employment as an element of occupational health.
- Support the organisational goals towards carbon reduction and sustainability.

Electric cargo bikes

There is specific learning for e-cargo bikes.

The right bike for the job

E-cargo bikes come in a variety of sizes with different configurations for carrying tools, packages etc. One of the benefits of the Triangulum 'try before you buy' approach was that staff could specify the most appropriate vehicle for their job – whether it was carrying files, paperwork or tools. This also addressed the issue of access to new models.

Expert knowledge

Working with an established supplier of e-cargo bikes and with experience of deliveries meant that that the project was able to draw on this knowledge. An understanding of payloads, loading and unloading and ergonomics mean the best solution could be identified. The design of a bespoke frame and cover for the Lunchbrakes trailer is a good example.

New entrants

Given the cost of e-cargo bikes, the loan model is beneficial to introducing opportunities for new users without making a commitment.

Parking and storage

Whilst car and van parking is given consideration as part of planning and building management, the requirements for bike and e-bike and e-cargo bike parking is less considered or not at all

Given the cost of e-cargo bikes (in the region of £5,000) there have been particular concerns about securing them. Whilst some of the programme e-cargo bikes have been stored in workshops, others have been taken into offices because of concern for security and some have been nervously secured in bike parking. They also benefit from being kept out of the weather.

Additionally, the e-cargo bikes are larger and heavier than traditional bicycles and staff need level access to storage so that they can be wheeled rather than carried. Bays also need to be large enough for e-cargo bike storage (and indeed non-traditional cycles).

Some trials with SMEs did not proceed beyond an initial trial due to storage challenges.

Charging

Increasingly e-bike design enables charging without removing batteries (which is easier and quicker for staff) so charging should be possible in bike storage areas beside each bay. The option of an additional battery for swap outs is beneficial, (the average range for an eCargo bike is 20-25 miles depending load and terrain)

Equipment and facilities

E-cargo bikes provide staff with agile access between sites – this should be complemented by secure accessible parking on all sites they might use, in addition to staff being provided with locks.

Staff should be provided with appropriate clothing – and places to store cycling clothing.

Facilities such as showers, changing rooms and lockers should be provided.

Further Information

Mobility Evaluation:

The evaluation work and report were undertaken by Beate Kubitz,

www.beatekubitz.com

beatekubitz@gmail.com

Infographics:

www.knownaim.co.uk

Triangulum Project:

www.triangulum-project.eu

Manchester Triangulum Consortium

Martine Tommis, Manchester City Council
m.tommis@manchester.gov.uk

Video Resources:

The EVs and e-cargo Bikes can be viewed in action on videos located
www.triangulum-project.eu

Glossary

EV	Electric vehicle In this document we refer to EVs which are fuelled solely by electricity, also known as battery electric vehicle (BEV). Cars and vans which retain a combination of an electric motor (which must be plugged in to be recharged) and a combustion engine (which requires petrol or diesel) are known as plug-in hybrid electric vehicles (PHEV).
E-bike	A bicycle with a small motor which assists the rider whilst they are pedalling. Electric power cuts off when the vehicle reaches approximatively 25 km/h (16mph). These bikes do not have a throttle and the motor does not operate if the bike is not being pedalled.
E-cargo bikes	A pedal-assisted bicycle (as described above) but with the capacity to carry luggage. Different models of e-cargo bikes are adapted with different means of carrying items including front or rear mounted trays, baskets and containers or seats for one or more children.
Grey fleet	Personal vehicles used by staff in the course of their work. Staff typically claim mileage for work use. Employers have a duty of care of staff using any vehicle (whether owned by staff or the organisation) so are responsible for checking that personal vehicles used in the course of work are fit for purpose.
ICE	A vehicle propelled with an internal combustion engine – fuelled with petrol, diesel and, more rarely, gas.
Telematics	These systems connect cars to the cloud based platforms. They can enable services such as remote and keyless vehicle locking, vehicle location tracking, vehicle systems monitoring (e.g. fuel consumption and service requirements), data collection and driver monitoring.

Figures

Tables