Report for the GSMA

The total cost of ownership for embedded mobile devices

Final report

11 November 2010

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Introduction by the GSMA, AT&T, Vodafone and Telenor Connexion

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Contents

Introduction **1**

1 Executive summary **3**

2 Background and rationale for this study **6**

3 Approach **9**
3.1 All costs during the lifetime of a device are included in the TCO 9
3.2 There could be constraints on mobile operators' ability to use spectrum flexibly 12

4 Findings from the study **15**
4.1 Around 90% of modules currently being deployed use 2G technologies 15
4.2 The communications module contributes only a small proportion of the TCO 16
4.3 The higher upfront costs of 3G modules are offset by lower on-going network costs and enforced replacement costs 18
4.4 Today's module choices could limit mobile operators' flexibility regarding their network strategies 21

5 Conclusions and implications for the industry **25**

Annex A: About the authors and Analysys Mason
Annex B: The GSMA and its Embedded Mobile programme
Annex C: Industry contributors
Annex D: The cost stack and detailed TCO results
Annex E: Calculations of replacements costs for 2G modules

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Introduction

By the GSMA, AT&T, Vodafone and Telenor Connexion

This report examines the total cost of ownership of Embedded Mobile (EM) and machine-to-machine (M2M) devices with the aim of highlighting how near term technology design decisions may create legacy device management issues for the mobile industry. The study is broad ranging and provides insight for today's decision makers in the EM ecosystem: the mobile network operators (MNOs), solution providers, manufacturers and end users, who will lead this new mobile market into the future.

The market for EM/M2M devices is expected to grow significantly in the coming years. New and traditional applications in business, industrial and consumer segments will be able to take advantage of the market drivers that are emerging today, such as near-ubiquitous mobile coverage, internationally harmonised radio frequency bands, and most importantly the explosion of new services that use higher rate mobile data communications technologies (e.g. UMTS, HSPA and in the future LTE).

However, EM/M2M devices will have different usage and lifecycle characteristics to the billions of mobile handsets in use today. Decisions made today on the deployment of these new embedded mobile devices may have long-term implications for the mobile networks that are expected to connect the numerous embedded mobile devices and carry their increasing traffic volumes. Product design decisions that are being made today may also have implications for the long-term costs of delivery for applications in sectors that are reliant on long-life modules and for those which entail high deployment or field-provisioning costs.

The GSMA is working to address many of the challenges facing the EM/M2M ecosystem through the GSMA's Embedded Mobile Programme. The programme aims to mitigate those challenges through market educational efforts such as this study and by working with companies from within and outside of the mobile eco-system in order to rapidly grow and scale the marketplace. We at the GSMA look forward to taking a leading role in developing and securing the future of ubiquitous embedded mobile.

Alex Sinclair

Chief Strategy Officer and Chief Technical Officer, GSMA

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Module costs are just one part of the equation when bringing the next range of connected devices and services to market. Other factors, including the cost of the device tied to volumes, unique requirements by vertical segments, certification process, provisioning, and support also share in the costs for a complete embedded solution. The good news is that as 3G multi-mode modules reach economies of scale, they are closing the cost gap with 2G modules and will help further reduce the total cost of ownership.

Glenn Lurie
President, Emerging Devices, Resale and Partnerships, AT&T

Mobile communication capabilities are becoming a critical and integrated part of various devices, machines and vehicles. Securing reliable and sustainable solutions for global deployments is key for this development. To further drive this development, close co-operation among all parties in the embedded mobile ecosystem and common understanding of the market characteristics is vital.

Per Simonsen
CEO, Telenor Connexion

With an ever-increasing desire for businesses to reduce costs, improve efficiency and increase customer retention, the demand for M2M services is set to increase significantly over the coming years. However, it will be crucial that the M2M ecosystem works together to drive standards, technology and approach in order to deliver the long-term, mass-market potential.

Erik Brenneis
Head of M2M at Vodafone Group

1 Executive summary

The use of embedded mobile technology in machine-to-machine and Internet-connected devices is gaining momentum. The number of Internet-connected applications and services is forecast to increase significantly over the coming years; applications will range from consumer devices such as e-books to vehicle monitoring systems and industrial control systems.

Most embedded mobile devices currently use 2G embedded modules (e.g. GSM), which have lower upfront costs than 3G modules. However, these *upfront costs* do not reflect all of the costs associated with embedded mobile devices, i.e. the *total cost of ownership (TCO)*. Importantly, the TCO includes traffic charges and potential 'end-of-life' costs which could arise in particular circumstances.

Mobile operators' decisions about future decommissioning of mobile networks and re-farming of spectrum are not likely to be driven by the embedded mobile market: this segment only contributes a small proportion of their revenue and network traffic. Thus, decisions on network strategy are likely to be made on the basis of the operators' strategies for mobile broadband services, which will dominate future traffic on mobile networks.

Nevertheless, today's decisions on the deployment of embedded mobile modules could constrain the way that mobile operators use their spectrum. Specifically, these decisions could have a disproportionate effect on operators' ability to decommission their 2G networks and re-farm their spectrum. For the most part, mobile operators are unaccustomed to considering legacy customer equipment issues when making decisions regarding network evolutions, because handsets have a relatively short product life. However, many embedded mobile devices have long lifecycles, potentially up to 20 years (e.g. smart meters for utilities). Therefore, decisions made today on the technologies used in such devices could have implications for many years to come. For instance, if the majority of embedded mobile devices sold continue to be 2G, then it is possible that 2G network decommissioning could trigger additional costs to replace legacy embedded mobile equipment.

In this report, commissioned by the GSMA, we investigate the total cost of ownership for embedded mobile devices, to provide a complete view of all costs incurred from design through to decommissioning. In particular, we consider the differences in the TCO between 2G and 3G devices. We examine the longer term consequences of encouraging the use of 2G modules in long service-life devices; this analysis explores what costs may arise from having to replace legacy devices if 2G networks are decommissioned as well as potential spectrum re-farming constraints and spectrum opportunity costs.

Our approach to this study has included in-depth interviews with 24 industry players across the embedded mobile ecosystem and several vertical sectors. We have also modelled in detail the various costs that contribute to the TCO. To illustrate some of the cost components, we have also considered the most likely spectrum re-farming scenario: that mobile operators decommission their 2G networks and re-farm this spectrum for 3G/4G technologies. Although we do acknowledge that there are other routes that mobile operators could follow, this scenario was selected on the basis of our experience of the industry and discussions with mobile operators. In this scenario, we have quantified the costs associated with replacing legacy 2G equipment. Our analysis, which has been informed by inputs from embedded mobile industry players, has led to a number of key findings:

Around 90% of modules currently being deployed use 2G technologies

Stakeholders gave several reasons for this, but key motives included 2G modules being cheaper and more mature (e.g. more energy-efficient, reliable and better supported by vendors).

The embedded communications module contributes only a small proportion of the TCO

We estimate that the cost of the communications module is only between 1% and 14% of the TCO, depending on the application. Our results also show that although network traffic costs can vary greatly between applications (from almost 0% to 65% of the TCO), for most applications they are much larger than the cost of the communications module. In the case of high-traffic applications, the network traffic costs are many times the communications module costs.

The higher upfront costs of 3G modules are offset by lower on-going network costs and enforced replacement costs

Across all applications that can be supported by either 2G or 3G modules, the upfront costs of 3G modules are higher than 2G modules. From our interviews, we understand that the cost of a 2G module is approximately USD20 (for 2011 deployments), while a 3G module is around USD47.[1] However, this difference in cost is expected to reduce over time, especially as 3G device volumes grow. For applications that generate significant traffic (e.g. commercial automotive management systems, or in-car Internet-enabled entertainment systems) the lower costs of 3G traffic over the lifetime of the device outweigh the higher upfront costs of 3G modules.

Once enforced replacement costs are taken into account, the TCO for 3G modules is lower than 2G for almost all applications in almost all scenarios. In the scenario where a mobile operator decommissions its 2G network ahead of its 3G network to re-farm the spectrum for 3G or 4G, enforced replacement costs would clearly only apply to 2G devices, which would need to be replaced. The applications with the highest amount of enforced replacement costs within the TCO are those with the longest lifetimes, and those with communications modules that cannot be replaced easily.[2]

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1 Although we note that this is not a "like for like" comparison, as 3G modules typically have better functionality than 2G devices.

2 Designers of devices with long lifespans (e.g. automatic meter readers) anticipate that the devices will require upgrades in communications technologies over their anticipated lifetime, and therefore design them so that the communications module can easily and quickly be replaced during a service visit. However, many other devices, such as those that need to operate in rugged environmental conditions, are not designed with a cost-effective way to replace just the communications module – in these cases the entire device must be replaced.

Today's module choices could limit mobile operators' flexibility regarding their network strategies

For the most part, mobile operators have typically not determined their network strategies for the next 15 to 20 years. Individual operators will choose different timing and technology strategies for network deployment and spectrum utilisation. However by deploying a higher number of 2G embedded mobile devices in the short term, operators may build in a constraint to their long-term network strategic options. Based on our interviews it is suggested that the most likely scenario is that most operators will decommission their 2G networks in the next 10 years. In this scenario, the industry could face large costs to replace legacy 2G embedded mobile devices (e.g. costs of over USD150 million for a representative Western European operator with 10 million subscribers). There would also be significant damage to brand image. What is not clear is whether mobile operators or embedded device vendors will be responsible for these costs. The lack of clarity on this topic could eventually be a cause for commercial disputes and delay in spectrum re-farming, which would be to the detriment of both the mobile industry and consumers.

By switching to predominantly deploying 3G devices now (which are 'multi-mode' and thus can operate over 2G networks), network operators could ensure more flexibility in their future network strategies, since the cost of decommissioning their 2G networks would be lower. Moreover, greater use of 3G devices would drive economies of scale and reduce the costs of 3G modules.

It should be noted that mobile operators do have an alternative option to replacing legacy 2G devices: to continue operating their 2G networks, and acquire additional spectrum for their 3G or 4G networks. However, we estimate that the cost of acquiring such spectrum and the cost of continuing to operate the 2G network are higher than the cost of a forced replacement of legacy 2G modules. In other words, the opportunity cost associated with this option is higher than the cost of the enforced replacement option.

In conclusion, our results show that in the majority of application scenarios 3G mobile devices have a lower TCO than their 2G equivalents. They also represent a more future-proofed solution: firstly they lead to mobile operators having more flexibility regarding their network strategies; and secondly, they are better equipped to meet future demand for embedded mobile applications (e.g. higher throughput or lower latency).

2 Background and rationale for this study

The use of embedded mobile technology in machine-to-machine (M2M) and Internet-connected devices is gaining momentum. It is forecast that a wide range of applications and services will be developed in the coming years, benefitting from mature and advanced radio technologies and improvements in network coverage. Future embedded mobile devices could, for example, include:

- traditional telemetry and M2M monitoring systems
- advanced diagnostic and control systems installed in a range of vertical sector applications (e.g. industrial field units, automotive private vehicle and fleet management)
- new Internet-connected consumer devices (e.g. video players, photographs, e-books and newspapers)
- enterprise and business equipment with wide-area mobile connectivity
- a plethora of connected devices for health monitoring, diagnosis and administrative systems.

These devices will have different usage characteristics from personal mobile handsets and mobile broadband devices such as laptops and USB modems/dongles. In some cases only periodic, non-time-critical data might be transmitted to and from the embedded mobile device; in other cases time-critical, high-bandwidth communications could be needed. The lifespans of embedded mobile devices will also be different, with some devices having long lifespans to achieve a return on the high upfront costs of deploying and installing these complex integrated devices.

Many embedded communications modules today use 2G technologies (e.g. GSM using SMS or GPRS data), which are relatively low-cost. In comparison, 3G modules[3] are more expensive to purchase than their 2G equivalents. However, these *upfront costs* do not represent *all* of the costs associated with the device, i.e. the *total cost of ownership (TCO)*. The TCO also includes costs such as testing, certification and provisioning. Also importantly, the TCO includes annual traffic conveyance charges and potential 'end-of-life' costs which could arise in particular circumstances.

Mobile operators' decisions about the decommissioning of their mobile networks and re-farming of spectrum[4] are not likely to be driven by the embedded mobile market: this segment only contributes a small proportion of their revenue and network traffic. Rather, network strategy decisions are likely to be made on the basis of the operators' strategies regarding mobile broadband services, which will dominate future traffic on mobile networks.

Nevertheless, today's decisions on the deployment of embedded mobile modules could constrain the way that mobile operators use their spectrum. Specifically, these decisions could have a

[3] We use the term 3G universally in this report to signify multi-mode 2G-3G devices. Our research programme indicated that there is little demand for 3G-only embedded communications modules.

[4] We define spectrum re-farming as changing the use of spectrum from one technology to another. Note that in the instance of re-farming spectrum from 2G to 3G technologies, it is possible for a mobile operator to re-farm some 2G spectrum without decommissioning its 2G network. If a decision is made to decommission the 2G network, then all 2G spectrum can be re-farmed for 3G.

disproportionate effect on mobile operators' ability to decommission their 2G networks and re-farm their spectrum.

Most mobile operators' revenue and traffic currently come from consumer handsets and devices, which typically have lifespans of two or three years. Mobile operators are therefore typically unaccustomed to considering legacy customer equipment issues when making decisions regarding network evolutions (unlike the broadcasting industry, which regularly faces such issues). However, many embedded mobile devices have much longer lifecycles, potentially up to 20 years (e.g. smart meters for utilities). Therefore, decisions made today on the technologies used in such devices could have implications for many years to come. For instance, if the majority of embedded mobile devices sold continue to be 2G, it is very possible that 2G decommissioning could trigger additional costs to replace legacy customer equipment, and these costs could be large. However, this would be reduced greatly if more 3G devices are deployed in the coming years.

In this report, which has been commissioned from Analysys Mason by the GSMA, we investigate the TCO for embedded mobile devices. Our objective is to provide a complete view of all costs associated with embedded mobile devices from design through to decommissioning, and to explore the associated implications for the use of mobile network spectrum in the long term. In particular, we consider differences in the TCO between 2G and 3G devices.[5]

We anticipate that this report will help to inform industry debate and quantify the potential impact caused by the installed base of legacy devices. Subsequently, this should enable all members of the embedded mobile ecosystem (e.g. mobile operators, device vendors, solution providers and purchasers of embedded mobile modules) to make more informed decisions regarding the development and deployment of embedded mobile devices in the coming growth years.

This report represents one element of the GSMA's embedded mobile programme, which aims to encourage the expansion of the global embedded mobile market by identifying and lowering the main barriers, developing common guidelines and driving innovation. More details of Analysys Mason, the GSMA and the embedded mobile programme are provided in the annexes to this report.

The remainder of this document is laid out as follows:

- Section 3 gives an overview of the approach taken during the study
- Section 4 presents our key findings on the TCO of embedded mobile devices, as well as the impact of current deployment choices on operators' network strategies
- Section 5 summarises our conclusions and the implications for industry players.

The report also includes a number of annexes containing supplementary material:

- Annex A provides an overview of the authors and Analysys Mason

5 As 4G networks are yet to be widely deployed, 2G or 3G modules are the likely options in the short- to medium-term.

- Annex B includes an overview of the GSMA and the Embedded Mobile Programme
- Annex C contains a list of industry contributors
- Annex D describes the cost stack and detailed TCO results
- Annex E provides details of our calculations of replacements costs for 2G modules.

3 Approach

Industry players are generally well aware of the upfront costs involved in embedded mobile solutions (e.g. equipment, provisioning) and the choice of network generation. However, they are often less aware of the potential long-term cost implications that should also be taken into account in designing embedded mobile modules for devices with long lifespans.

Our approach to calculating the total cost of ownership (TCO) aims to capture the relevant *upfront deployment and on-going network costs that are likely to be incurred during the whole lifetime of an embedded mobile device*. We also include in our calculation the additional costs that would arise if there is an unplanned enforced replacement of legacy 2G devices – e.g. if a network operator seeks to decommission its 2G network. Our approach has two parts, which are detailed further in the remainder of this section:

- the costs included in the TCO
- assessment of the constraints on mobile operators' ability to use spectrum flexibly.

3.1 All costs during the lifetime of a device are included in the TCO

The TCO of an embedded mobile device includes all of the cost elements that are incurred during the development, manufacture, deployment and usage of the device. We refer to these costs collectively as the *cost stack*. The cost stack represents the build-up of different cost elements, broadly in the order in which they are incurred. The embedded mobile device cost stack is illustrated in Figure 3.1 below, along with the different roles played by the main industry players in influencing the development of the overall solution.

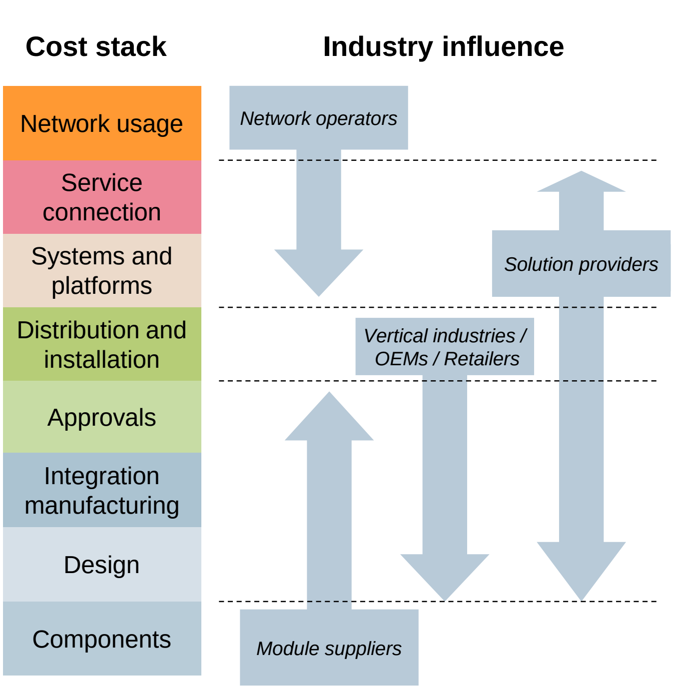

Figure 3.1: Cost stack showing industry influence [Source: Analysys Mason]

The elements of the cost stack are described in Annex D. From our research, we were able to build up a picture of where different types of players have traditionally been active, and in which parts of the cost stack they have exerted their influence. We developed detailed estimates for each element of the cost stack, but for clarity the results are summarised under three categories: the costs of the *Comms module*, *Design and provisioning*, and the *Network*.

We gathered inputs and estimates for the TCO calculation from a range of stakeholders. We interviewed or gained questionnaire responses from 24 industry players across the embedded mobile ecosystem and several vertical sectors. The organisations[6] are listed in Annex C, and include:

- 6 mobile network operators, in particular their M2M divisions
- 5 wireless module designers, developers and/or manufacturers
- 4 solution and/or platform providers
- 7 vertical-sector-specific suppliers (industrial, healthcare, automotive, utility)
- 2 players in the retail/consumer space.

A wide range of information informed our analysis and supported our views and findings, such as:

- differences between cellular communications technologies
- differences between vertical sector applications
- aspects of the value chain, such as which parties make the decisions and which parties bear the burden of costs
- differences in cost and other factors between 2G and 3G solutions, and other technical aspects

6 Three interviewees requested not to be named in this public report.

- provisioning and other costs for various vertical sector and M2M applications
- device lifetimes, replacement requirements and upgrade issues.

We received qualitative and quantitative responses from the contributors, which enabled us to apply real-world detail and industry experience to our estimates for cost elements in different applications and situations.

We have chosen a selection of vertical sector applications to show the range of TCOs under different network and usage situations (see Figure 3.2 below). This choice of applications is broadly illustrative of the mix of different types of embedded mobile devices that any given mobile operator might support. They are not intended to be a comprehensive list of all possible embedded mobile applications.

Sector	*Applications*
Utilities	Automatic meter readers Smart utility grid hubs
Transport	Commercial vehicle tracking Fleet management, information, diagnostics and control Private vehicle theft/e-call Private vehicle monitoring and diagnostics In-car entertainment and navigation
Patient monitoring	Elderly patient monitors Hi-tech mobile medicine diagnostic machines
Industrial	Industrial monitors and trackers Industrial remote control, management and monitoring
Domestic security	Home security monitoring systems
Retail	Point-of-sale, kiosk and other mobile retail
Consumer/household	Household appliances, home control and entertainment equipment Personal devices (excluding personal cellular handsets, smartphones and laptop data modems)

Figure 3.2: Vertical sector applications chosen to illustrate the TCO [Source: Analysys Mason]

The TCO reflects the costs of the embedded mobile solution over and above the costs of the unconnected solution. Therefore the costs of the host devices in the upfront costs are not included within the TCO. We have modelled the costs by year over the lifetime of the embedded mobile solution, before discounting the costs to beginning of its life, using a discount factor of 12%.[7] We have then considered the TCO for devices developed and deployed in 2011, in order to inform the decisions to be made in the embedded mobile ecosystem in the immediate future. Whilst in

7 Of course the broad range of players in the embedded mobile value chain are likely to use different discount rates. In our experience a pre-tax nominal discount rate of 12% represents a reasonable average.

practice decisions on embedded mobile technologies will be made continuously during the development of the market, *it is the decisions to be taken in 2011 which have most relevance today*.

Our calculation of the TCO also reflects costs that are controlled by different parties in the overall solution – so while the purchaser ultimately pays for the overall solution costs (e.g. including network usage charges), the mobile operator makes the cost-based decisions on how it will deploy and operate its mobile network.

We calculated network-related costs using our estimates, informed by interview responses in a number of instances:

- **The proportion of modules in operation, split by 2G and 3G**. We consider that applications which demand higher data rates would tend to use 3G modules, while more traditional M2M services would initially tend to use mature 2G technologies. As 3G device costs decrease over time, we expect 3G solutions to account for a larger proportion of sales.
- **Traffic per module.** We estimated the annual number of Mbytes of traffic that the different types of applications would generate on a daily, weekly or monthly basis, growing year-on-year as applications become more data-intensive.
- **Mobile network operator fees**. We used the result of an Analysys Mason mobile network cost model as a proxy for the average costs[8] of 2G and 3G data traffic per MB, plus network connection costs per device to estimate the overall network cost element.

3.2 There could be constraints on mobile operators' ability to use spectrum flexibly

In addition to calculating the TCO of 2G and 3G devices, we also specifically considered the potential constraints that the installed base of embedded mobile devices could have on how mobile operators use their spectrum. Notably, the continued use of spectrum for 2G technologies specifically for embedded mobile devices has an opportunity cost, as this spectrum could otherwise be used for newer technologies (i.e. 3G or 4G).

Most mobile operators worldwide currently operate two mobile networks: a 2G network and a 3G network. A handful of mobile operators have also launched 4G LTE networks[9], and widespread deployment of 4G networks is expected in the next few years. This situation presents a number of challenges to mobile operators:

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8 The proxy used for the average cost per MB was as calculated by Analysys Mason's cost model for the Dutch regulator OPTA: 2G MB – USD0.19 falling by 2% p.a.; 3G MB – USD0.17 falling by 6% p.a. (based on a mix of low-speed and high-speed usage). Therefore, for services that have metered charging, we forecast the cost per MB to be: 2G – USD0.18 in 2015 and USD0.16 in 2020; 3G – USD0.12 in 2015 and USD0.09 in 2020. We note that traffic costs calculated by such cost models only represent the cost incurred by the operator, plus a reasonable rate of return. Of course, the operator may charge embedded mobile device users a higher retail rate. Therefore, the network costs in our TCO calculations represent a lower bound.

9 E.g. TeliaSonera in Sweden.

- Operating three networks simultaneously is expensive.
- Take-up of new mobile services (e.g. mobile broadband, smartphones) is rapidly increasing the amount of traffic on operators' networks.
- These new services increasingly require 3G or even 4G networks, leading to a growing demand for spectrum for 3G and 4G services.
- Later technologies (advanced 3G, such as HSPA+, and 4G) can transmit more data using a fixed amount of spectrum (i.e. they are more efficient in their use of spectrum than 2G technologies). 2G is less efficient in trying to cope with this growing data demand.

Mobile operators are therefore considering the strategic options for their mobile networks – in particular, when they should re-farm their spectrum from one technology to another. There are a range of options available for operators to manage their spectrum, including:

- decommissioning their 2G networks and re-farming the spectrum for 3G or 4G networks – although the coverage of the 3G or 4G networks would need to be improved to match the current coverage of 2G
- continuing to operate 2G networks (given their almost ubiquitous coverage for voice services), decommissioning 3G networks and moving straight to 4G networks as the primary means of providing mobile broadband services.

That said, we understand from our interviews that the most likely scenario is that mobile operators will decommission their 2G networks. Indeed, in our interviews some stakeholders stated such plans, and mobile operators in markets such as Japan, South Korea and Australia have already re-farmed some of their 2G spectrum. Therefore, for the purposes of this study, we assume that this scenario will occur.

As discussed in our introduction to this report, today's decisions on the deployment of embedded mobile modules could reduce operators' flexibility in the way that they use their spectrum. Specifically, these decisions could have a disproportionate effect on mobile operators' ability to decommission their 2G networks and re-farm their spectrum. Many embedded mobile devices have long lifecycles, potentially of up to 20 years (e.g. smart meters for utilities). Therefore, decisions made today on the technologies used in such devices could have implications for many years to come. If the majority of embedded mobile devices sold continue to be 2G, then 2G decommissioning could incur large costs to replace legacy customer equipment. However, this would be reduced greatly if more 3G devices are deployed in the coming years. We note that it is not entirely clear who would incur such replacement costs – the mobile operator, providers of embedded module solutions, or industry suppliers.

We note that mobile operators do have an alternative option to replacing legacy 2G devices: they could retain a minimal amount of spectrum to continue operating their 2G networks, and acquire additional spectrum to provide additional capacity for their 3G or 4G networks. However, under this option, an operator would continue to incur costs to operate and maintain the 2G network and would also require expensive low-frequency spectrum (e.g. 800–900MHz) in order to maintain 2G coverage. As a result, we estimate that the opportunity cost associated with this option is higher than the costs of the enforced replacement option.

Capturing enforced replacement costs in the TCO

As part of our TCO calculations, we also captured the incremental costs that would be incurred in the case of an enforced replacement of 2G legacy devices. As discussed earlier, we present the TCO for devices deployed in 2011. For the purposes of this scenario, we assume that mobile operators choose to decommission their 2G networks in 2020, which we believe represents a likely timescale for an operator in a developed country. In our interviews, one operator informed us that it intended to decommission its 2G networks across Europe by 2020. In more developing countries, we anticipate decommissioning dates to be beyond 2020.

In order to calculate the TCO, we estimated the number of legacy 2G devices that could remain in operation in 2020. We also took into account the anticipated lifetime of the 2011 device and the proportion of its original economic lifetime that is remaining in 2020. Clearly, applications which use a high proportion of 2G modules with longer lifetimes will have proportionally larger enforced replacement costs – examples include automatic meter readers, industrial monitors, and automotive theft/e-call systems.

We also include the additional cost elements that are likely to be incurred in replacing the device, such as:

- a new 3G communication module (including design and approvals)
- integration manufacturing, provisioning and service connection
- replacement of (part of) the host machine for some vertical sector applications (e.g. when the communications module is integrated into a device and it is not possible or practical to separately switch out the communications module alone[10]).

10 For example, the communications module is integral to an elderly patient monitor, which would need to be replaced entirely with the latest monitor (with 3G capability). Similarly, industry responses suggest that it is not viable for a motor engineer to open up the ruggedised and encased vehicular M2M system and attempt to replace only the communications module – instead the entire part would be swapped out as a single unit.

4 Findings from the study

This section presents the findings from our interviews with industry stakeholders and our quantitative analysis. In summary:

- Around 90% of modules currently being deployed use 2G technologies.
- The communications module contributes only a small proportion of the TCO.
- The higher upfront costs of 3G modules are offset by lower on-going network and enforced replacement costs.
- Today's device choices could limit mobile operators' flexibility regarding their network strategies.

4.1 Around 90% of modules currently being deployed use 2G technologies

Anecdotal evidence from our interview programme suggests that around 90% of modules currently being deployed in embedded mobile devices use 2G technologies. This is for several reasons:

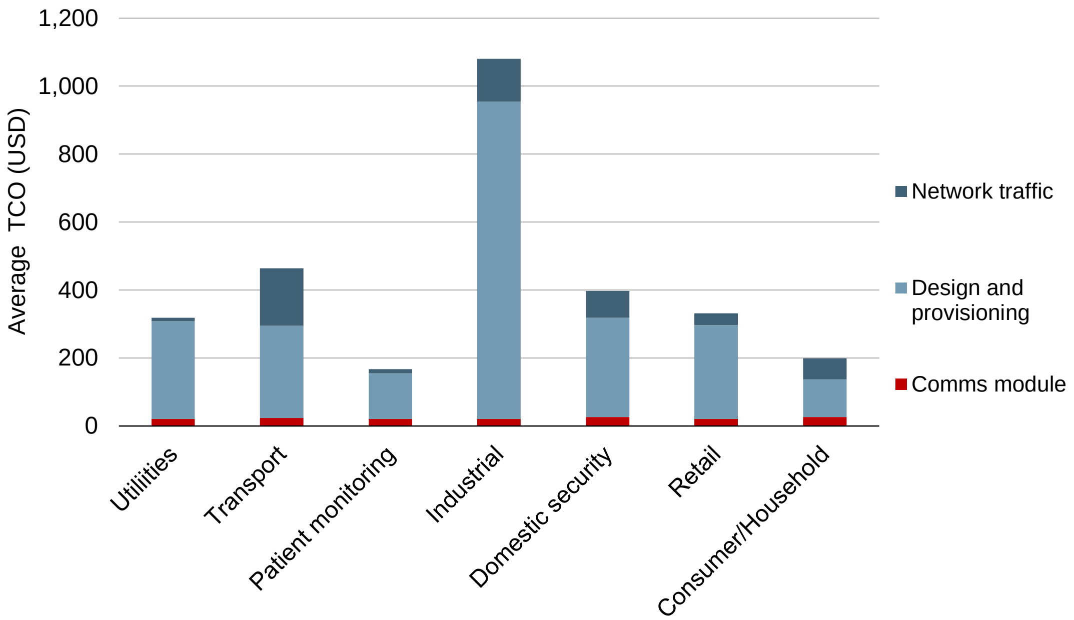
- 2G technologies are seen as mature – they are viewed as being reliable, energy-efficient, internationally recognised and supported by a wide range of module vendors.
- 2G modules are cheaper and purchasers are unwilling to spend more for 3G devices – this is especially important for large-scale deployments.
- 2G technology performance is seen as 'good enough' for most applications as the communication *session size* is small and the total amount of data transferred is low.
- 2G coverage is seen as superior to 3G – especially for indoor and rural or remote applications, although we note that the 3G embedded devices used are nearly always 'multi-mode' and therefore have the same coverage for 2G data rate services.
- The potential implications of re-farming 2G spectrum are not a concern for purchasers of embedded module devices who are thinking only 5–6 years ahead.

3G modules are chosen for a minority of applications, also for several reasons:

- Some applications require greater throughput than can be provided by 2G – this is especially the case for video streaming, video security, in-car Internet applications, complex fleet management applications and smart utility grid hubs.
- Some applications require the lower latency provided by 3G.
- Some purchasers of applications with long lifetimes are concerned about the long-term viability of 2G devices due to potential 2G spectrum re-farming.

4.2 The communications module contributes only a small proportion of the TCO

Figure 4.1 below shows examples of the average TCO of embedded mobile devices deployed in 2011 in various by vertical sectors.[11] For each segment, the figure shows an aggregated version of the cost stack that was introduced in Section 3.1 (detailed versions of this information showing all cost stack elements can be found in Annex D).



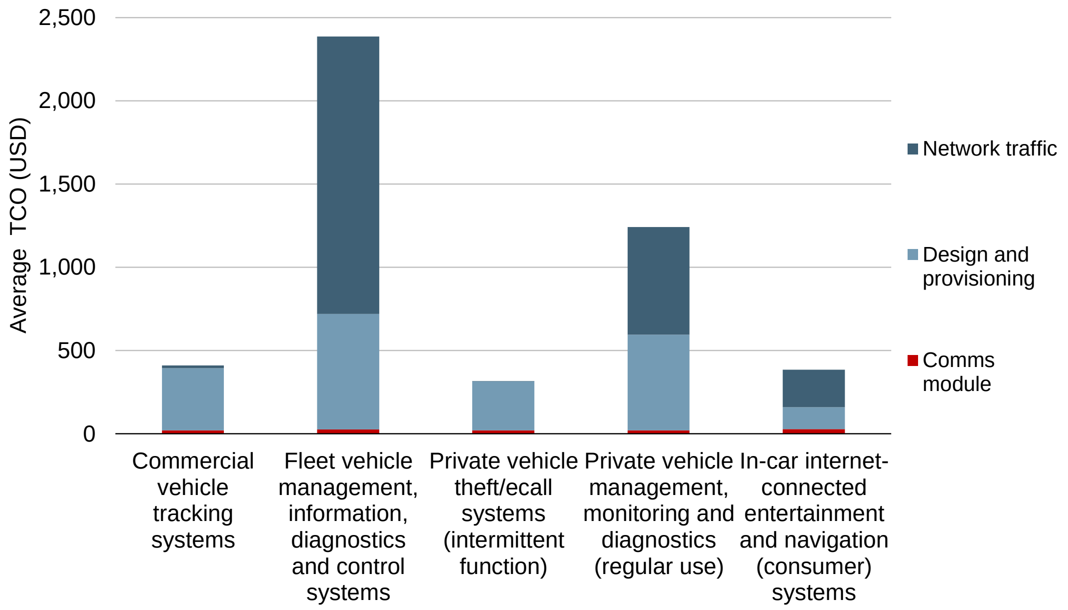
20	23	21	20	25	20	26	Comms module (USD)
6%	**5%**	**12%**	**2%**	**6%**	**6%**	**13%**	**as a % of TCO**

Note: This figure excludes the cost of the host device (e.g. the cost of the utility meter for automatic metering applications). These are Global average results: the communications module cost shown is an average mix of 2G and 3G modules within the vertical sector. These results are shown before the inclusion of enforced replacement costs for legacy devices.

Figure 4.1: TCO for embedded mobile devices deployed in 2011 [Source: Analysys Mason, 2010]

It can be seen that the TCO of an embedded mobile device varies dramatically between broad vertical sectors: for some areas such as patient monitors and diagnostics or consumer/household devices, the TCO can be less than USD200, while for others such as industrial applications it can be many times higher. Within the broad vertical sectors, the TCO also varies dramatically between individual applications. For example, as illustrated in Figure 4.2 below, the TCO for individual applications within the transport sector ranges from less than USD400 for private vehicle theft and e-call systems, to over USD2000 for fleet vehicle management, information, diagnostics and control systems. Applications within the other broad vertical areas also show a similar wide range of TCOs.

11 Note that these TCO results are simply *examples* of vertical applications and are not intended to represent all applications in the vertical.



20	25	25	21	28	Comms module (USD)
5%	**1%**	**6%**	**2%**	**7%**	**as a % of TCO**

Note: Global average results. The communications module cost shown is an average mix of 2G and 3G modules within the application. These results are shown before the inclusion of enforced replacement costs for legacy devices.

Figure 4.2: *Average TCO for embedded mobile devices deployed in 2011 in the transport sector [Source: Analysys Mason, 2010]*

Probably the most striking result in the above charts, is that ***the communications module contributes only a small proportion of the TCO***. This also varies little between vertical sectors. Depending on the vertical sector and application, the cost of the communications module is only between 1% and 13% of the TCO. Furthermore, as the TCO excludes the cost of the host device, the communications module as a proportion of the overall device cost is even lower. This percentage tends to be higher for low-cost consumer devices (e.g. an Internet-connected mobile picture frame) than for high-cost industrial applications. The results also highlight two other trends: firstly, design and provisioning typically constitute a large proportion of the TCO; and secondly, network costs can vary greatly between applications. We discuss these trends below.

Design and provisioning typically constitute a large proportion of the TCO

This category includes a range of costs: design, certification, integration manufacturing, approvals, distribution, installation, enterprise systems/platforms/software and network systems/platforms. These costs vary significantly across applications, but they nevertheless typically constitute a large proportion of the TCO. Design and provisioning can account for over 85% of the TCO for many low-traffic devices (e.g. automatic meter readers, automotive theft/e-call systems). For example, from our interviews we understand that:

- Some applications have approvals and certification processes which increase product development costs. This is particularly the case for devices with long lifespans; applications with short lifespans do not need long term standards and can be more flexible. Examples of such processes include: automotive manufacturers have specific approval processes, and healthcare regulatory approvals and certification can be particularly lengthy and complex.

- Regarding integration manufacturing, some devices require expensive ruggedisation for -50°C to +80°C environments; other local CPUs and housing can be 10 times the cost of the communications hardware.

- A major cost element is the management infrastructure to provision, configure and manage the device on the network, and these costs depend on whether it uses a standard or a proprietary protocol.

- There are additional systems and costs required to support fixed IP addresses for devices.

Network costs can vary greatly between applications

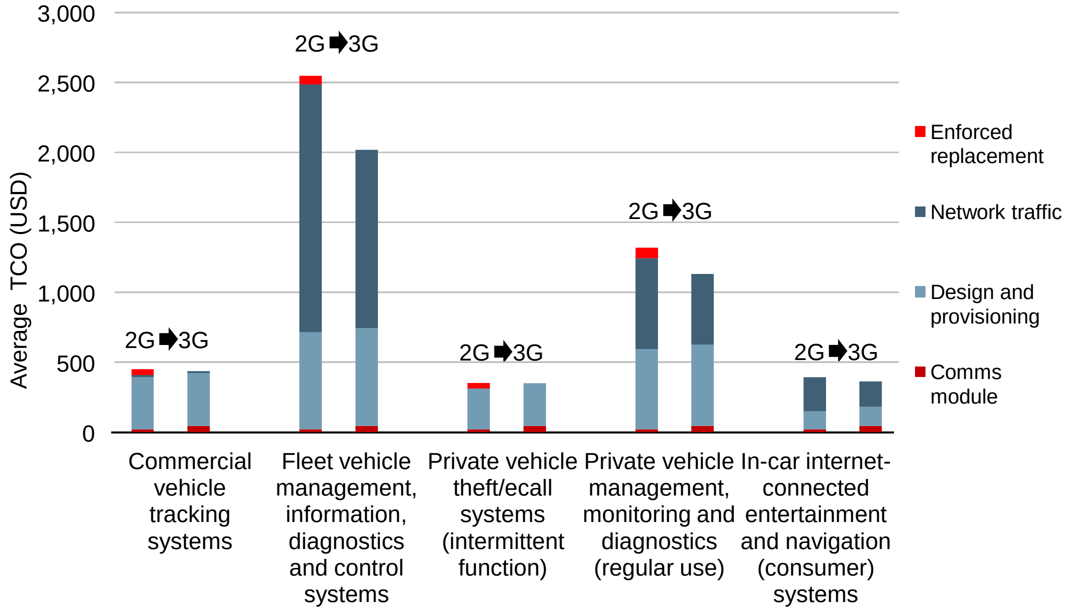
The amount of traffic that a device generates, and subsequently the network costs per MB of the device, varies dramatically. This can be from almost 0% of the TCO for automotive theft/e-call systems, which are only programmed to generate traffic in rare emergency situations, up to 65% of the TCO for fleet vehicle management systems, which very frequently communicate large amounts of data (e.g. hourly vehicle status updates, performance parameters and location information). This result was confirmed by some of the opinions put forward in the interviews:

- Connectivity costs do not typically have a large impact unless there are high data volumes.
- Complex applications for monitoring and controlling large industrial devices can transfer hundreds of MB per month, with additional complexity for real-time data, local computing, back-up resilience, etc.

As discussed in Section 3.2, if mobile operators choose to decommission their 2G networks in the short-to-medium term, legacy 2G modules will need to be replaced. This will likely be a costly exercise, and applications which use a high proportion of 2G modules with longer lifetimes will therefore have proportionally larger enforced replacement costs (e.g. automatic meter readers, industrial monitors, automotive theft/e-call systems). We investigate this issue in more depth in the next two sections.

4.3 The higher upfront costs of 3G modules are offset by lower on-going network costs and enforced replacement costs

As discussed previously, when deciding whether to deploy 2G or 3G modules, operators, solution providers and module purchasers often focus on the upfront costs of the module and do not take into account the full TCO. Therefore, we have explicitly investigated the differences in the TCO for 2G and 3G devices. The results for the transport sector are given below in Figure 4.3.



20	47	20	47	20	47	20	47	20	47	Comms module (USD)
5%	**11%**	**1%**	**2%**	**6%**	**14%**	**2%**	**4%**	**5%**	**13%**	**as a % of TCO**

Note: Global average results. Each pair of columns shows the 2G and 3G TCO for the same application, including different 2G and 3G communications module and traffic costs, and the proportionate amount of enforced replacement costs for 2G devices.

Figure 4.3: Comparison of the TCOs for 2G and 3G embedded mobile devices deployed in 2011 in the transport sector [Source: Analysys Mason, 2010]

The TCO for 2G devices is higher than 3G devices

This is true not only in the transport sector, as illustrated above, but in all applications in all vertical sectors in almost all scenarios. This is because the higher upfront costs for 3G (for communications module and design) are more than offset by the lower on-going network traffic costs, and also because of the potential enforced replacement costs associated with 2G devices. We note that provisioning costs rarely differ between 2G and 3G modules.

Across all applications the upfront costs of 3G modules are higher than 2G modules

From our interviews, we understand that the cost of a 2G module is approximately USD20 (for 2011 deployments), while a 3G module is around USD47. This difference is driven by a number of factors:

- 2G devices are currently sold in much higher volumes than 3G devices, and therefore benefit from greater manufacturing economies of scale.
- 3G modules are typically of a higher specification than 2G modules, and include multi-mode 2G components.

- The intellectual property (IP) costs per unit for 3G modules are higher than for 2G modules, although these costs may decrease as volumes increase.

In addition to the cost of the module, the design and approvals costs for 3G modules are slightly higher than for 2G.

However, for high-traffic applications, the higher upfront costs are more than offset by lower 3G network traffic costs

Although the network traffic costs can vary substantially between applications, these costs are usually higher than the costs of the communications module. In the case of high-traffic applications, the network traffic costs are many times the communications module costs.

We forecast that the network traffic costs per MB will fall more quickly for 3G than for 2G as 3G networks become more heavily utilised and as embedded mobile devices make greater use of HSPA services that will become increasingly available with 3G modules (and will achieve lower costs per MB).

For many applications that generate significant traffic (e.g. commercial automotive management systems, in-car Internet-enabled entertainment systems) the lower costs of 3G traffic over the lifetime outweigh the higher upfront costs of 3G modules. However, for applications that do not generate significant traffic (e.g. automatic meter readers, automotive e-call and theft systems) the extra cost of using a 3G module is larger than the savings from lower costs of 3G traffic.

Once enforced replacement costs are taken into account, the TCO for 3G modules is lower than 2G for almost all applications

If mobile operators decommission their 2G networks ahead of 3G networks to re-farm the spectrum for 3G or 4G, enforced replacement costs would clearly only apply to 2G devices, which would need to be replaced. If operators choose other network strategies, the results differ. For example, if an operator chooses to retain its 2G network, decommission its 3G network and deploy a 4G network, many of the 3G modules would need to be replaced with 2G/4G modules to accommodate certain applications with requirements that cannot be provided by 2G technologies (e.g. high throughput, low latency).

The applications with the highest amount of enforced replacement costs within the TCO are:

- those with the longest lifetimes, as they are more likely to still be in use if 2G decommissioning occurs
- applications with communications modules that cannot be replaced easily.[12]

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[12] Designers of devices with long lifespans (e.g. meter readers) anticipate that the devices will require upgrades in communications technologies over their anticipated lifetime, and therefore design them so that the communications module can easily and quickly be replaced. However, many other devices are not designed with a viable way to replace the communications module – in these cases the entire device must be replaced.

Our results show that in almost all scenarios the TCO of 2G devices is higher than 3G devices. The only instance where this is not the case is for some low-traffic applications in the scenario where 2G is not decommissioned until a much later time (e.g. 2025). If 2G decommissioning occurs earlier (e.g. 2015 or 2020), then even for low-traffic applications, the TCO for 2G devices is higher than for 3G devices.

4.4 Today's module choices could limit mobile operators' flexibility regarding their network strategies

As discussed in Section 3.2, decisions made today regarding the deployment of embedded mobile devices could constrain the way that mobile operators use their spectrum. Specifically, these decisions could have a disproportionate effect on operators' ability to decommission their 2G networks. If operators choose to decommission their 2G networks, they will incur high costs to replace legacy 2G embedded mobile devices.[13]

In order to illustrate the potential enforced replacement costs, we considered a representative Western European[14] mobile operator (defined as having 10 million traditional mobile subscribers) in the context of the following two scenarios:

- *predominantly 2G modules* sold in the coming years
- *predominantly 3G modules* sold in the coming years.

These two scenarios are illustrated in Figure 4.4 below. The chart on the left-hand side shows the proportion of 2G devices that are sold under the two different scenarios. The 'predominantly 2G' profile shows that 2G devices continue to be sold for a considerable number of years and the percentage of 2G devices in the overall mix does not fall below 5% until 2018. The 'predominantly 3G' profile in the left-hand side of the chart shows a much quicker reduction in the proportion of 2G devices that are sold into the market; in this case, 2G devices as a proportion of the total number sold is less than 5% by 2014. The outcome of the two scenarios affects the total number of 2G devices on an operator's network. In the case of our representative operator, the right-hand side of Figure 4.4 shows a continued build-up of 2G devices under the 'predominantly 2G' scenario with a peak being reached around 2017. The accumulation of 2G devices is much less severe in the 'predominantly 3G' scenario because the proportion of 2G devices being sold into the market is much lower. Note that the right-hand side chart only shows 2G devices – the population of 3G devices is not shown for simplicity of presentation.

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13 As discussed, it is not clear that mobile operators will incur these costs as opposed to end users, industry suppliers or support organisations.

14 We have developed a global calculation containing eleven different regions or large countries. This means that we can investigate the potential costs of 2G device replacement for a variety of typical situations. See Annex E for more details.

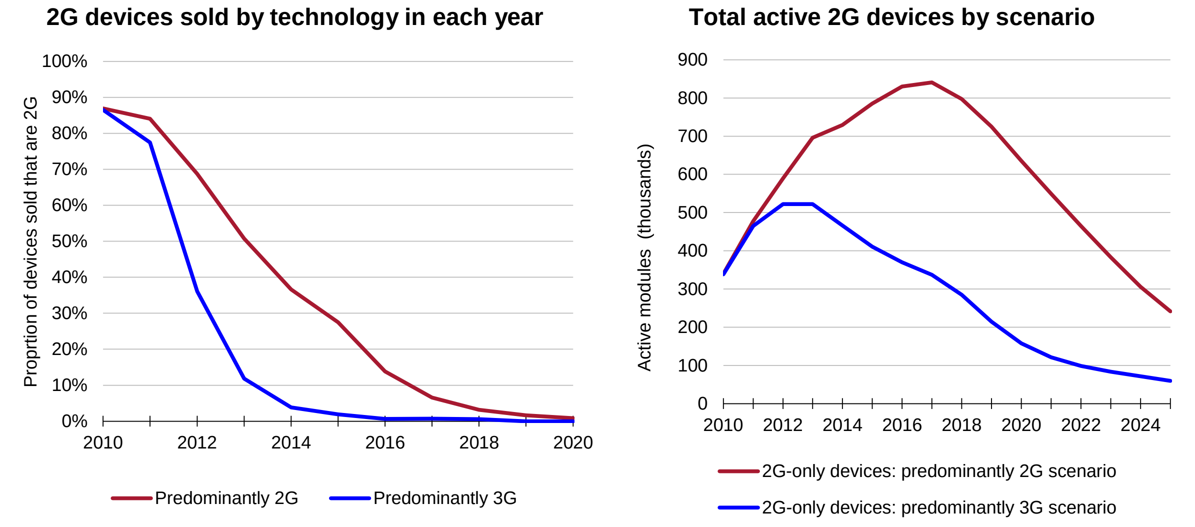


Figure 4.4: Illustration of input and output of device technology scenarios [Source: Analysys Mason]

Decisions about re-farming approaches, and particularly the timing of re-farming, could vary between individual operators. For illustrative purposes, we have considered three different dates for 2G decommissioning: 2015, 2020 and 2025. For each of these cases, the total number of legacy 2G modules that need to be replaced will differ based on historical sales and devices that have already been retired.

Figure 4.5 below summarises the cost in the decommissioning year of replacing all remaining legacy 2G modules for a representative Western European operator. The results are presented for three different decommissioning years and in each case we compare the costs for the 'predominantly 2G' and 'predominantly 3G' scenarios.

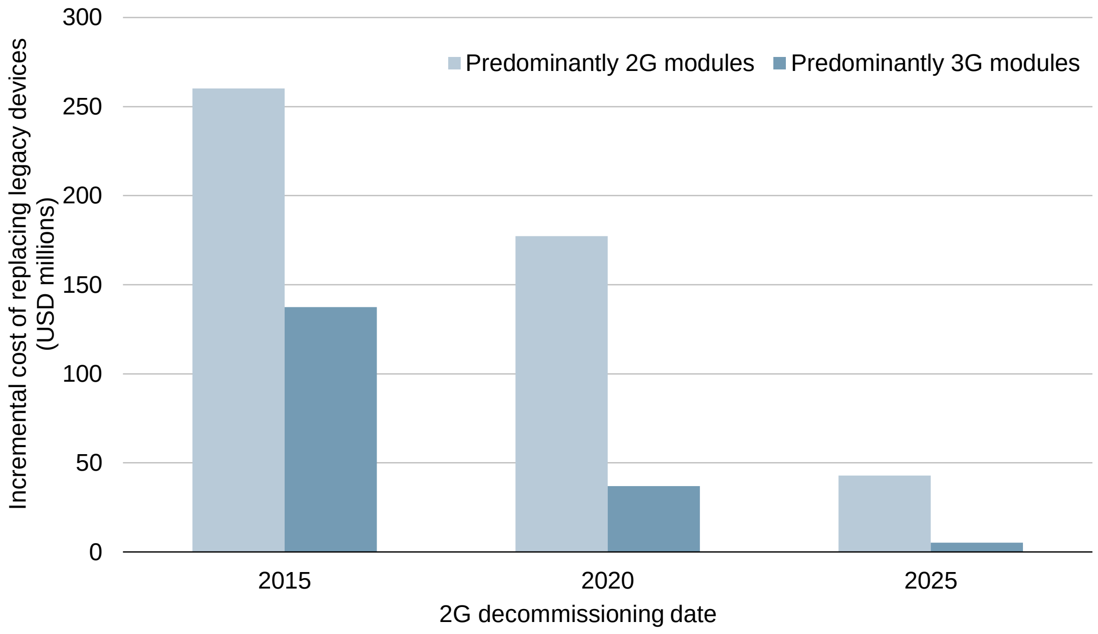


Figure 4.5: *Incremental cost of replacing legacy 2G modules for a typical West European mobile operator[15] under two scenarios for module sales [Source: Analysys Mason, 2010]*

In the scenario where predominantly 2G modules are sold in the coming years, if the operator chooses to decommission its 2G network in 2020 (which we believe represents a likely date for an operator in a developed country), the cost could be over USD150 million. If the operator chooses to decommission its 2G network earlier, this cost increases to over USD250 million in 2015. If, on the other hand, the operator does not decommission its 2G network until 2025, the replacement cost falls to less than USD50 million. This is because the majority of 2G modules will reach the end of their lifespan before 2025 and be replaced by 3G or 4G devices.

However, as shown in Figure 4.5, if a decision is made now to predominantly deploy 3G modules, the industry could avoid much of this replacement cost, as well as damage to the operators' brand image from the disruption caused by having to replace 2G devices.

For additional perspective on this cost, we have also calculated the results for representative North American and Indian operators:

- For a typical North American operator (with 50 million traditional mobile subscribers) the replacement cost in 2020 could be USD1 billion.
- For a typical Indian operator (with 100 million traditional mobile subscribers) the replacement cost could be USD400 million.

15 A typical Western European mobile operator has 10 million traditional mobile subscribers (approximately 2% of the total Western European market). The incremental cost reflects only the proportion of the remaining economic life of the original module, but includes a share of the host costs for some vertical sector applications which involve the scrapping of integral hardware.

Earlier we noted that mobile operators do have an alternative option to replacing legacy 2G devices: to continue operating their 2G networks, and acquire additional spectrum for their 3G or 4G networks. We forecast that the traffic generated by the legacy 2G embedded modules will be a small proportion of network load, therefore the occupancy of low frequency spectrum (e.g. 800–900MHz) to provide a 2G coverage network for legacy embedded modules is not likely to be an effective use of frequencies. We estimate that the costs to acquire such spectrum and the costs to continue to operate the 2G network are higher than the costs of a forced replacement of the legacy 2G modules. In other words, the opportunity cost associated with this alternative option is higher than the costs of the enforced replacement.

5 Conclusions and implications for the industry

Most embedded mobile devices currently use mature 2G technologies (e.g. GSM). Industry stakeholders see several reasons for this, but one particularly important reason appears to be the higher upfront costs of 3G devices compared to 2G devices – specifically the higher costs of a 3G embedded communications module. However, our research and quantitative analysis have shown that ***the total cost of ownership (TCO) is lower for 3G embedded mobile devices than for 2G devices***. In particular:

The embedded communications module contributes only a small proportion of the total cost of ownership (TCO)

- We estimate the cost of the communications module is only between 1% and 14% of the TCO, depending on the application. Our results also show that although network traffic costs can vary greatly between applications, from almost 0% to 65% of the TCO, for most applications they are much larger than the cost of the communications module. In the case of high-traffic applications, the network traffic costs are many times the communications module costs.

The higher upfront costs of 3G modules are offset by lower on-going network costs and enforced replacement costs

- Across all applications that can be supported by either 2G or 3G modules, the upfront costs of 3G modules are higher than 2G modules. However, this difference in cost is expected to reduce over time, especially as device volumes grow.

- For applications that generate significant traffic (e.g. commercial automotive management systems, in-car Internet-enabled entertainment systems) the lower costs of 3G traffic over the lifetime outweigh the higher upfront costs of 3G modules.

- Once enforced replacement costs are taken into account, the TCO for 3G modules is lower than 2G for almost all applications in almost all scenarios. In the scenario where a mobile operator decommissions its 2G network ahead of its 3G network to re-farm the spectrum for 3G or 4G, enforced replacement costs would clearly only apply to 2G devices, which would need to be replaced. The applications with the highest amount of enforced replacement costs within the TCO are applications with the longest lifetimes, and applications with communications modules that cannot be replaced easily.

Today's module choices could limit mobile operators' flexibility regarding their network strategies

- For the most part, mobile operators have typically not determined their network strategies for the next 15 to 20 years. Individual operators will choose different timing and technology strategies for network deployment and spectrum utilisation. However by deploying a higher number of 2G embedded mobile devices in the short term, operators are building a constraint on their long-term network strategic options. We believe that the most likely scenario is that most operators will decommission their 2G networks in the next 10 years. In this scenario, the industry could face large costs to replace legacy 2G embedded mobile devices, as well as significant damage to its image.

- By switching to predominantly deploying 3G devices now (which are multi-mode and thus can operate over 2G networks), network operators would have more flexibility in their future network strategies given that the costs associated with decommissioning 2G networks would be lower.

- It should be noted that mobile operators do have an alternative option to replacing legacy 2G devices: to continue operating their 2G networks, and acquire additional spectrum for their 3G or 4G networks. However, we estimate that the costs to acquire such spectrum and the costs to continue to operate the 2G network are higher than the costs of a forced replacement of legacy 2G modules.

These findings have a number of implications for purchasers of embedded mobile modules and solution providers, as well as for mobile operators.

Implications for module purchasers and solution providers

- ***Module purchasers and solution providers should consider investing in the higher upfront costs for 3G embedded mobile modules*** for many applications because 3G devices have lower on-going traffic costs. Application upgrades to make use of higher data rates in the future could also be applied without a hardware replacement.
- Adopting 3G embedded mobile modules earlier rather than later will ***reduce module purchasers'/solution providers' exposure to changes in mobile operators' network deployments***. This is especially important for applications that have long lifespans.
- If mobile operators choose to decommission their 2G networks***, legacy embedded modules will at least face significant disruption to services*** during the replacement process, and it is ***unclear who would incur the costs*** to replace the legacy 2G devices.

Implications for mobile operators

For the most part, mobile operators are yet to determine their network strategies for the next 15 to 20 years. Indeed, there are many options available to them and their plans over such a long timeframe are far from certain. However:

- By deploying a higher number of 2G embedded mobile devices in the short term, they are ***building a constraint on their long-term network strategic options***.
- By switching to predominantly deploying 3G (multi-mode) devices now, ***they would have more flexibility in their future network strategies***.

Annex A: About the authors and Analysys Mason

A.1 Analysys Mason's consulting services

Analysys Mason offers consulting services that span the entire business development cycle from strategy development through to planning, implementation and review. We help clients in the public and private sectors to make the best possible business decisions on a wide range of issues including investment, strategy, policy, procurement, network roll-out and market entry.

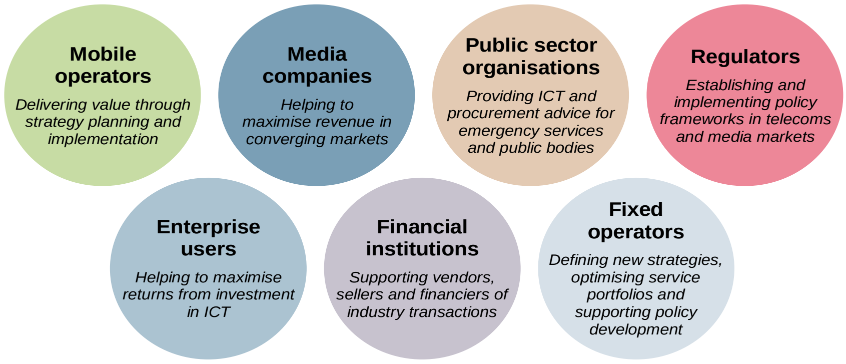


Figure A.1: Analysys Mason's wide range of clients in many industry sectors [Source: Analysys Mason]

For more than 20 years, we have been working with a range of global clients to resolve critical issues by applying our intellectual rigour, passion and expertise. For more information about our consulting services, please visit www.analysysmason.com/consulting.

A.2 Analysys Mason's Research Division

Analysys Mason provides a portfolio of subscription research services that help organisations to understand major strategic shifts and country- and region-specific trends in the telecoms industry. Through granular market data and forecasts, and independent qualitative analysis, we help clients to make informed strategic decisions, reduce risk and benchmark their performance.

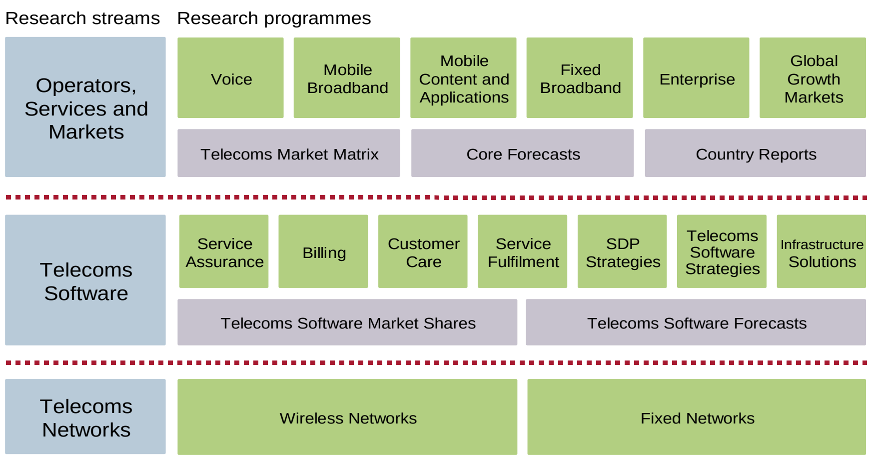


Figure A.2: Analysys Mason's subscription research portfolio [Source: Analysys Mason]

In addition to its subscription-based content, Analysys Mason also offers a custom research service, which helps clients to answer specific questions. For more information about our subscription research programmes and custom research services, please visit www.analysysmason.com/research.

A.3 The project team

Lee Sanders (Partner) leads the majority of Analysys Mason's spectrum management projects and has advised regulators, government bodies and operators worldwide. He has led several of Analysys Mason's high-profile spectrum-related studies for regulators, including advising Ofcom on the awards of the 2.6GHz band, the digital dividend and the L-Band, as well as our study for the European Commission on the digital dividend.

Ian Streule (Senior Manager) is one of Analysys Mason's most experienced modellers, having designed and built numerous models of mobile markets, technologies, services, costs, spectrum and revenues since joining the company in 1998. Ian has managed or directed a number of our high-profile mobile cost modelling projects on mobile service costs (particularly wholesale termination services) for industry regulators and operators in most regions of the world.

Gilles Monniaux (Lead Consultant) is an experienced consultant with over 10 years of experience in the telecoms sector. He has particular expertise in spectrum regulation as well as general regulatory experience. Most recently he has been involved in a number of fixed and mobile regulatory cost modelling projects.

Annex B: The GSMA and its Embedded Mobile programme

The GSMA

The GSMA represents the interests of the worldwide mobile communications industry. Spanning 219 countries, the GSMA unites nearly 800 of the world's mobile operators, as well as more than 200 companies in the broader mobile ecosystem including handset makers, software companies, equipment providers, Internet companies, and media and entertainment organisations. The GSMA is focused on innovating, incubating and creating new opportunities for its membership, all with the end goal of driving the growth of the mobile communications industry.

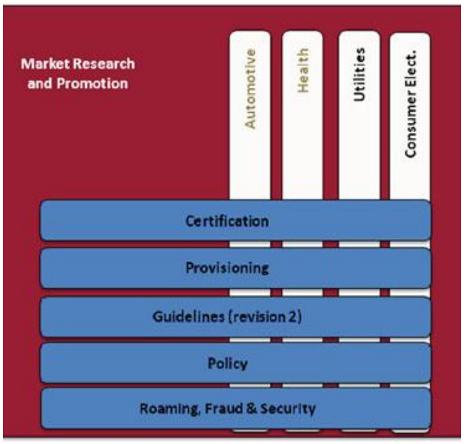
The Embedded Mobile programme

With a particular focus on the automotive, utilities and healthcare sectors, the GSMA's Embedded Mobile programme aims to catalyse the expansion of the global embedded mobile market by identifying and lowering the main barriers, developing common guideline and driving innovation.

The programme's short-term goal is to trigger market expansion to achieve 500 million connected embedded mobile devices by 2013:

- partnering with the automotive, utilities and healthcare sectors
- fostering innovation
- facilitating and enabling scale.

The Embedded Mobile programme includes work streams across three main areas:



- *Market Enablers* – with the remit of addressing and reducing the roadblocks that currently impede market development, such as test and certification, business processes, provisioning, and regulatory issues
- *Vertical Markets* – with a focus on the support and acceleration of market trials across the healthcare, automotive and utilities sectors, the business case for embedded mobile and deepening the understanding of success factors and additional roadblocks
- *Marketing* – with a focus on developing messaging, initiating market research and sharing best practices.

Annex C: Industry contributors

Our work included conducting interviews and gathering questionnaire responses from a range of players involved in the design, manufacture, provisioning and support of M2M and embedded mobile solutions. Below we list 21 of the contributors to our research and briefly describe their activities, as stated on their respective websites. Three interviewees requested not to be named in this public report.

Industry contributor	*Short description of the company*
AgoraBee	AgoraBee S.A. (www.agorabee.com) is a Swiss company operating in the new information technologies field, specialized in security, parking lots, logistics and the petrochemical industry. AgoraBee offers innovative solutions combining performance, efficiency and user pleasure in a rapidly growing market of “communicating objects” and information technologies.
Amscreen M2M	Amscreen M2M (www.amscreenm2m.com) is a UK company that provides connectivity products and services to manufacturers and service providers enabling them to unlock the value of data stored within their remote equipment. Born from the acquisition and history of Comtech M2M, a pioneering leader and patent holder in M2M technology, Amscreen is set to revolutionise the “machine connectivity” market.
AT&T Enterprise	AT&T is the largest communications holding company in the world by revenue. AT&T Enterprise (www.business.att.com/enterprise) is an innovative leader in M2M, with a proven track record in telematics, security solutions, monitoring, Supervisory Control and Data Acquisition (SCADA), point of sale, asset management and similar M2M deployments. AT&T’s innovative service delivery platforms complement our network and expertise for a broad range of wireless data applications and industries.
Cambridge Consultants	For 50 years, Cambridge Consultants (www.cambridgeconsultants.com) has led the way in innovative product development. Cambridge Consultants is the development partner of choice to many of the world’s leading blue chips as well as the virtual development team for ambitious start-up companies.
EcoAxis Systems	EcoAxis (www.ecoaxisindia.com) has created an M2M communication technology platform for control and remote monitoring of industrial plants & equipment. This technology provides previously unavailable value for key stakeholders. Leading (Indian) companies in the energy, environmental and discrete equipment segments have deployed complete product solutions from EcoAxis. This platform has immense potential for use in a wide range of segments and applications.

eSUNTech Canada Inc	eSUNTech (www.esun-tech.com) has been in the business of helping customers, systems integrators and other solution providers improve their processes and mobile applications since 2001. It has a history of innovation and remain at the forefront of new technology development. It constantly looks for opportunities to deliver more value to its customers by advancing their enterprise mobility systems through partnerships. eSUNTech offers enterprises of all sizes the ability to rapidly and cost-effectively gain insight into their business, provide real-time data at the point of activity and enable the deployment of emerging IT technology.
fieldcloud SAS	fieldcloud (www.fieldcloud.com) is a new generation provider of data logistics services and consulting. It works mainly in the energy sector (oil and gas, electricity) but also has solutions for other verticals.
iMetrik	iMetrik Solutions Inc. (www.imetrik.com) is an innovator in embedded wireless tracking M2M solutions that enable companies to reduce cost and increase control of remote assets. Hundreds of thousands of vehicles are currently tracked in its network, with another 10 000 added monthly.
Isabella Products	Isabella Products, Inc. (www.isabellaproducts.com) was founded in February 2008 as a next-generation consumer wireless products and services company with a clear objective of producing high-value products for a variety of consumers. Isabella focuses on creating intuitive, simple and innovative devices by leveraging the very latest in hardware, software and wireless technologies to create a rich user experience.
Janus Remote Communications	As part of the Connor-Winfield family of companies, Janus (www.janus-rc.com) is uniquely positioned to provide all elements of your custom M2M solution, from hardware and firmware design, to software engineering, to PCB and component manufacturing. The extensive internal resources it has available enable it to provide customers with the exact product to meet their specific needs in a cost-effective and timely manner.
Jasper Wireless	Founded in 2004, Jasper Wireless (www.jasperwireless.com) is a privately held company based in Sunnyvale, California with regional offices in the UK. The Jasper Wireless platform enables network operators to quickly and efficiently service the M2M market, and for their M2M customers to optimally run their connected device businesses. The company partners with network operators around the world.
MedApps	MedApps (www.medapps.com) is dedicated to developing innovative telehealth solutions that deliver seamless connectivity to electronic health records, promote patient wellness and reduce healthcare costs by improving patient compliance.
Qualcomm	Qualcomm Inc. (www.qualcomm.com) is the world leader in next-generation mobile technologies. For 25 years, Qualcomm ideas and inventions have driven the evolution of wireless communications, connecting people more closely to information, entertainment and each other. Today, Qualcomm technologies are powering the convergence of mobile communications and consumer electronics, making wireless devices and services more personal, affordable and accessible.
Red Bend Software	Red Bend software (www.redbend.com) helps mobile phone manufacturers and network operators to accelerate the adoption of new services and features, respond rapidly to customer needs, and reduce support costs through mobile software management solutions.

ROAMWORKS	ROAMWORKS (roamworks.com) is a software and solutions provider in the specialized sector of remote asset management with commercial offices in Dubai, UAE and Virginia, USA along with a software and hardware development centre in Bonn, Germany. Its software platform, ROAM (Remote Operational Software Management), application suite and comprehensive solutions provide organizations the ability to track and monitor, in real-time through wireless telecommunication networks (satellite or terrestrial), their mobile and/or fixed assets remotely.
Sierra Wireless	Founded in 1993, Sierra Wireless (www.sierrawireless.com) has a track record of leading the way with new wireless technologies and solutions. It focuses on wireless devices and applications, offering a comprehensive portfolio of products and services that reduce complexity for its customers. With sales, engineering, and research and development teams located in offices around the world, it also offers a network of experts in mobile broadband and M2M integration to support customers worldwide.
Telenor Connexion	Telenor Connexion (www.telenorconnexion.com) is a leading global provider of managed M2M connectivity solutions. Building on more than 10 years of M2M experience, Telenor Connexion is constantly exploring new fields in this rapidly growing business. Companies in industries as diverse as automotive, security, utilities and fleet management are implementing our M2M solutions to achieve productivity gains, cost management, environmental improvement and to expand customer services.
Telit	Telit Communications PLC (www.telit.com) develops, manufactures and markets M2M modules which enable machines, devices and vehicles to communicate via wireless networks.
Deutsche Telekom	Deutsche Telekom AG (www.telekom.com) is one of the world's leading telecommunications and information technology service companies. Deutsche Telekom recently launched an International Competence Centre for M2M communications to focus on M2M products and services in nine different market segments: Transport & logistics, vehicle telematics, smart metering / smart grid, consumer electronics, security, retail & commerce, industrial automation monitoring and control, healthcare and public sector & infrastructure.
TRAAKiT / Radaw Limited	The TRAAKiT (www.traakit.co.uk) service keeps watch over whatever you want, (well almost whatever you want), and alerts you when the situation changes. You decide the boundaries where you want your 'prized possession' to be and tell us. TRAAKiT sets up an Invisible Fence on its servers and then watches your 'prized possession' periodically. If your 'prized possession' strays outside the Invisible Fence, then TRAAKiT lets you know.
Vodafone Medium & Large Business Division	Vodafone Group Plc (www.vodafone.com) is the world's leading mobile telecommunications company, with a significant presence in Europe, the Middle East, Africa, Asia Pacific and the United States through the Company's subsidiary undertakings, joint ventures, associated undertakings and investments.

Figure C.1: Industry contributors [Source: Company websites]

Annex D: The cost stack and detailed TCO results

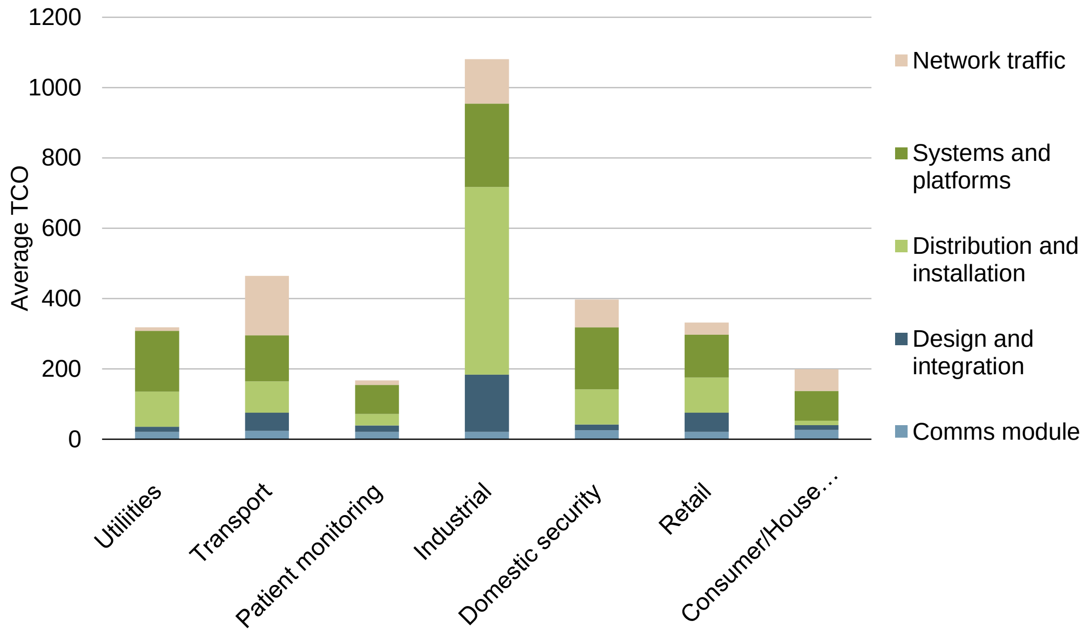
D.1 The cost stack

The elements of the cost stack are described below.

Cost element	*Brief description*
Components	Chipset and intellectual property rights for the communications module.
Design	Overall design and planning of the embedded mobile solution.
Integration manufacturing	Embedding the communications module into the host device. This includes the costs of housing, connectors, power supply, environmental resilience, etc. *This does not include the host device costs.*
Approvals	Testing, certification and approval of the embedded mobile device with industry bodies, network providers, etc.
Distribution and installation	Distribution and installation of the embedded mobile device. *This does not include the host cost/sales margin.*
Systems and platforms	Enterprise systems and software to enable the embedded module to interact with the users' back-office systems.
Service connection	Provisioning the SIM account into the network systems (HLR, GSN) as well as intelligent network platforms, network portals, IP address management and user/SIM management on the network side. Network roaming and security requirements are integrated here.
Network usage	Switching and conveyance of device traffic (MB), sometimes roaming on networks away from the home network. Network usage charges also compensate the mobile operator for any associated spectrum fees.

D.2 Detailed TCO results

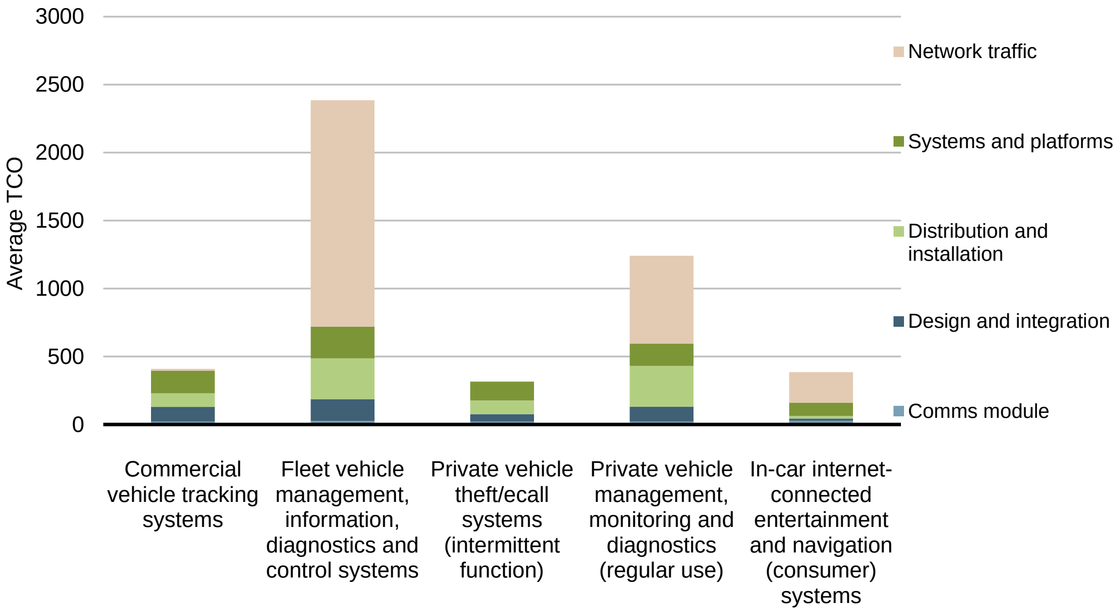
In the main body of this report we illustrate the TCO according to a summary of the cost stack. In Figure D.1 below we represent the results from earlier, this time illustrating further details from the cost stack. In particular the "design and provisioning" cost is split between "systems and platforms", "distribution and installation" and "design and integration".



20	23	21	20	25	20	26	Comms module (USD)
6%	**5%**	**12%**	**2%**	**6%**	**6%**	**13%**	**as a % of TCO**

Figure D.1: *Detailed 2011 TCO results (in USD) for embedded mobile devices by vertical sector [Source: Analysys Mason]*

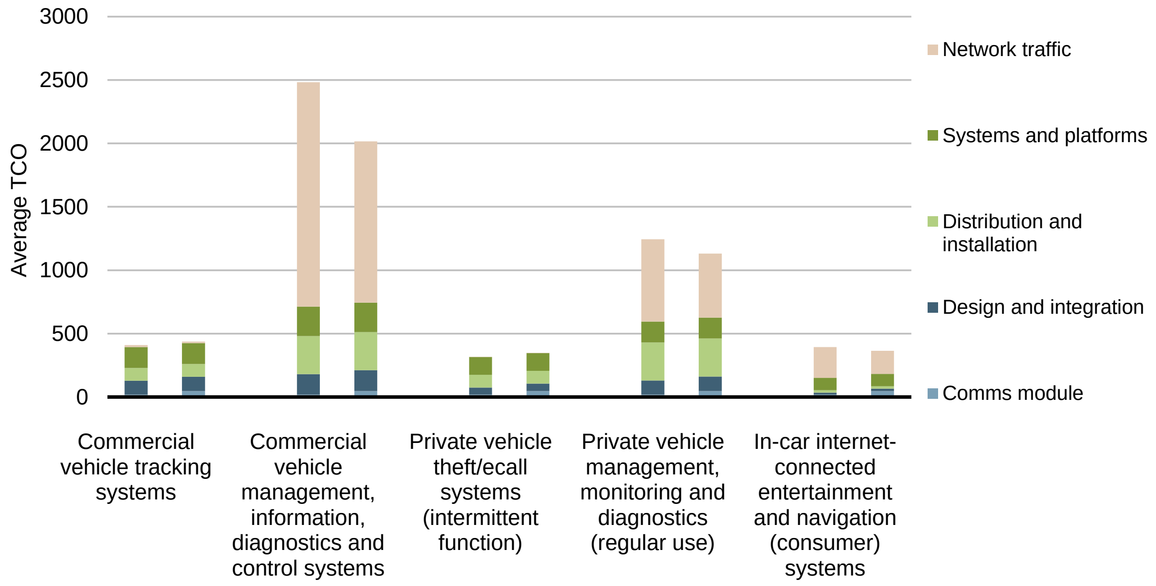
As discussed in Section 4.2, the TCO of an embedded mobile varies dramatically between broad vertical sectors: for some areas such as patient monitors and diagnostics or consumer/household devices, the TCO can be less than USD200, while for others, such as industrial applications, it can be many times higher. During our interview research, suppliers to the automotive and industrial sectors informed us that designing the embedded device and integrating the comms module into the machine were significant activities. For example, automotive devices must be designed to withstand frequent temperature cycles from -40°C to +80°C; industrial devices may need to cope with vibration, dust and other environmental factors. We also found that industrial applications were often low-volume bespoke installations for which there were limited economies of scale in distribution, and often individual installation costs. The costs of testing and certification (approvals) also vary by application.



20	25	25	21	28	Comms module (USD)
5%	**1%**	**6%**	**2%**	**7%**	**as a % of TCO**

Figure D.2: Detailed 2011 TCO results (in USD) for embedded mobile devices in the transport sector [Source: Analysys Mason]

As discussed in Section 4.2, the TCO varies dramatically between individual applications. For example, the TCO for individual applications within the transport sector range from less than USD400 for private vehicle theft and e-call systems, to over USD2000 for fleet vehicle management, information, diagnostics and control systems.



20	47	20	47	20	47	20	47	20	47	Comms module (USD)
5%	**11%**	**1%**	**2%**	**6%**	**14%**	**2%**	**4%**	**5%**	**13%**	**as a % of TCO**

Figure D.3: Detailed 2011 TCO results (in USD) for 2G and 3G embedded mobile devices in the transport sector [Source: Analysys Mason]

As discussed in the main report, the TCO of 3G devices is almost always lower than that of 2G modules. This is predominately due to the fact that the higher upfront costs of 3G devices is more than offset by the lower on-going traffic costs and potential enforced replacement costs.

The other costs (the "systems and platforms", "distribution and installation" and "design and integration") vary little between 2G and 3G devices. One notable exception is that the design and approvals costs for 3G modules can be slightly higher than for 2G.

Annex E: Calculations of replacements costs for 2G modules

Our calculation of the replacement cost is based upon an overall device forecast by 2G and 3G technologies, taking into account:

- typical device lifetimes and replacement profiles
- the tendency of low- and high-rate embedded mobile solutions to use 2G and 3G communications technology respectively.

Short-term decisions made on the deployment of 2G modules in the expanding embedded mobile market will have a significant impact on the number of legacy devices still in use in the future. We expect that legacy 2G devices will, over the coming 10 to 15 years, decline and be replaced with newer technologies. However, due to the long service lives of particular applications, a proportion of the 2G modules deployed in 2011 and beyond are likely to still be on 2G networks in 2015, 2020, and to a lesser extent in 2025. With this issue in mind, the aim of our forecast was to highlight the representative embedded mobile applications that might exist in a mobile network operator's portfolio, and not to provide a definitive view of the total market opportunity.

We have developed a detailed calculation model for the growth, deployment and replacement of 2G and 3G embedded mobile devices over the period from 2010 to 2025, with the option to analyse 2G decommissioning in 2015, 2020 or 2025. It primarily aims to calculate the TCO for devices sold and activated in 2011, so that our findings can be used to inform current industry decisions and developments. We have also used our calculation to determine the total replacement costs for legacy 2G modules that are forecast to still be in operation at the potential decommissioning dates for 2G networks. An outline of our calculation methodology is show in Figure E.1.

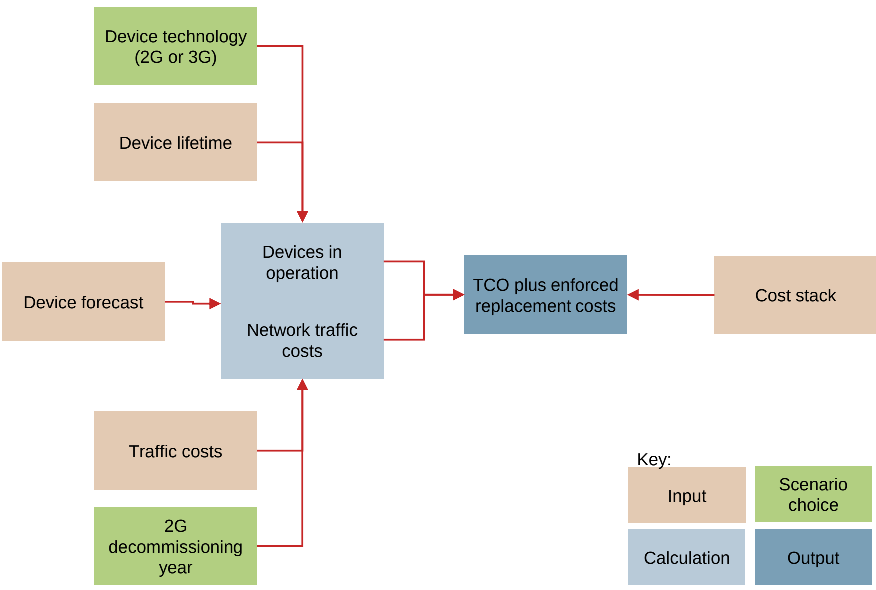


Figure E.1: Calculation methodology [Source: Analysys Mason]

This annex summarises the various inputs to the calculation that we have used to arrive at the total replacement costs, covering:

- forecast
- dimensions
- scenarios
- lifetime profiles
- legacy devices in operation
- replacement cost estimates.

E.1 Forecasts

The forecast total number of devices in operation globally for *our list* of embedded mobile devices is shown in Figure E.2. During our research we have found that the definition of what is included in an embedded mobile device forecast varies considerably between the projections published by different organisations. Some forecasts include mobile phones, data cards and devices using local-area wireless technologies. As such, care should be taken when comparing forecasts.

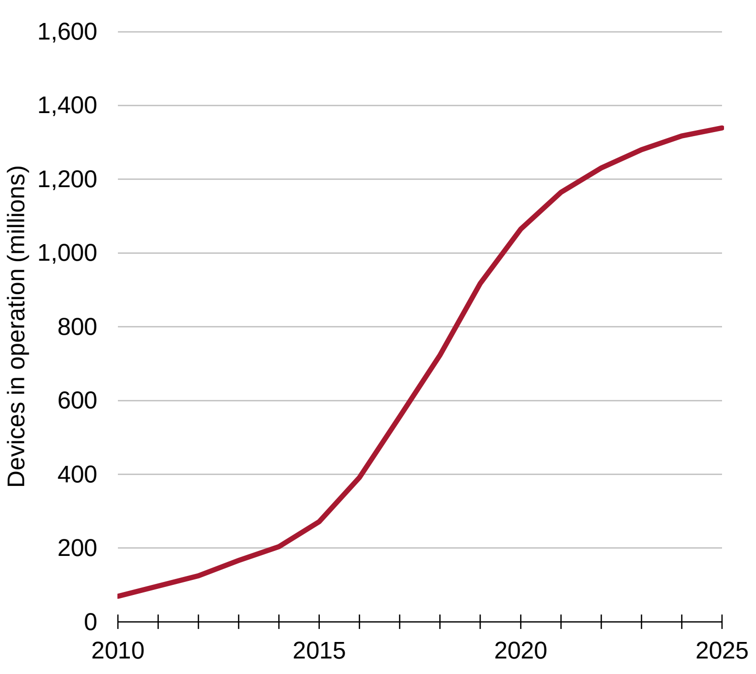


Figure E.2: Embedded mobile device forecast used in the calculations [Source: Analysys Mason]

E.2 Dimensions

- **Global regions and countries** – the model is dimensioned on eleven major regions and countries (Western Europe, Eastern Europe, North America, Latin America, Middle East and North Africa, Sub-Saharan Africa, Japan, Australia, China, India, rest of the world) with the facility to take a selected market share for a typical network operator within each region.
- **Time periods** – annually 2010 to 2025.
- **Illustrative applications and devices** – as shown in Annex D.

E.3 Scenarios

We have defined two main parameters to determine the number of legacy 2G devices that could face enforced replacement in the event of 2G network decommissioning:

- **Device technology** – as shown in Section 4.4 in the report we have considered two scenarios for the proportion of 2G and 3G modules that are sold to module purchasers in the coming years: *predominantly 2G modules*, or *predominantly 3G modules*

- **2G decommissioning year** – as discussed in Section 4.4 of the report, we have adopted three possible 2G decommissioning years: 2015, 2020 and 2025.

E.4 Lifetime profiles

We have applied a lifetime profile to the 2G devices deployed in each year, in order to calculate how many operational devices are replaced with the latest *choice* of technology over time. These lifetime profiles are set by an average lifetime, and a normal distribution curve around the average lifetime. The lifetime profile is provided in Figure E.3 below for *smart utility grid hubs*, and illustrates a number of our assumptions for this application:

- The minimum lifetime for such devices is five years, therefore no devices are replaced within the first five years. Therefore, we assume that 100% of devices are still in operation in the first five years of being deployed.
- The maximum lifetime is 15 years, therefore all devices are replaced within the first 15 years. Therefore, we assume that 0% of devices are still in operation after 15 years of being deployed.
- The average lifetime is 10 years. Therefore we assume that 50% of devices are still in operation after 10 years of being deployed.

In other words, although we specify an average life for a smart grid hub of 10 years, we allow the service life of individual smart grid hubs to vary. However, all devices will remain in service for at least 5 years and all will be replaced within 15 years.

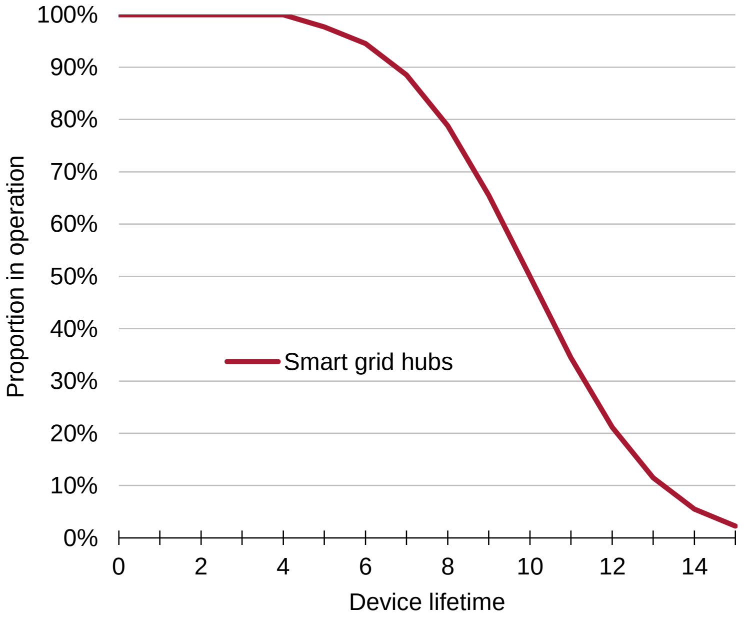


Figure E.3: Estimated lifetime profile [Source: Analysys Mason]

E.5 Legacy devices in operation

The combination of our *forecast for the illustrative embedded mobile devices*, the *device technology scenario*, and the *lifetime profiles* leads us to a total number of 2G devices in operation over time. We calculate this separately for each region/country, and this can also reflect the number of devices which a typical operator in a region would have (based on the typical regional market share for a typical established operator). Figure E.4 below illustrates the projected number of legacy 2G devices in operation over time, shown for our total global forecast and for a typical Western European network operator (with 10 million traditional voice subscribers).

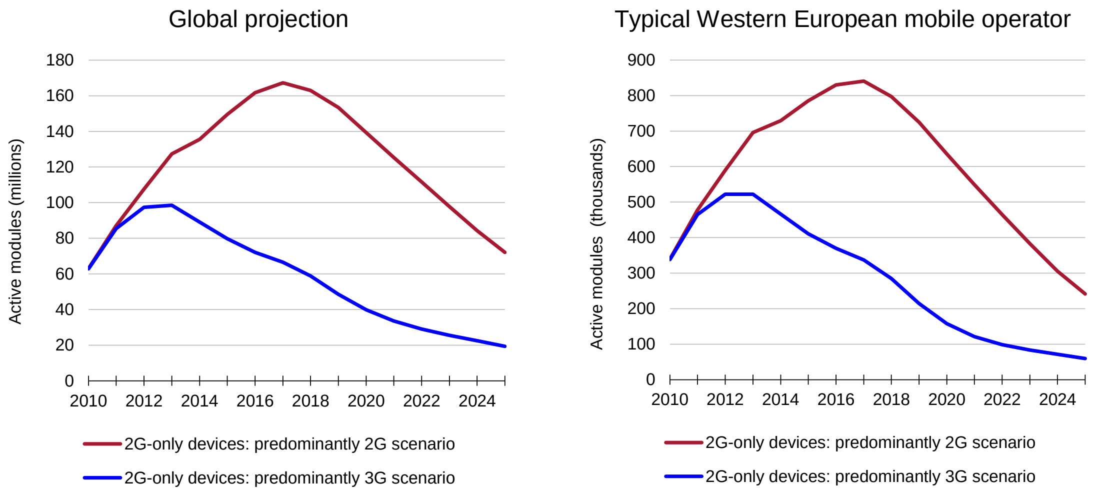


Figure E.4: Legacy 2G devices in operation by device scenario [Source: Analysys Mason]

E.6 Replacement cost estimates

We have used our cost stack estimates to build up the likely replacement costs that would be incurred if legacy 2G devices are required to be replaced. The enforced replacement cost (which would have to be borne by the industry, or passed on to end users and consumers) varies considerably depending on the application: for consumer devices and household systems, the enforced replacement cost amounts to what it would cost to replace the unit including the communications module (e.g. a satnav device, mobile-connected digital camera, etc.), which could amount to around USD150. For industrial or automotive systems, which involve field recalls, service engineers, and potentially new equipment housings for the new 3G communications module and associated local processors, we expect that the replacement costs would be in excess of USD1000 per device.

Overall, from our projected base of legacy 2G embedded mobile devices, the average replacement cost is around USD600. The relevant costs are reduced to reflect the remaining economic lifetime of the originally deployed assets, from around USD400 (in 2015), to USD150 (in 2025).

The product of *legacy 2G devices in operation* and the *estimated replacement costs* (reduced for remaining lifetime) results in our estimates for the total costs that the mobile operators and/or other industry players would face from enforced replacement in the event of 2G decommissioning.

The calculation we have developed allows us to extract results for individual applications and/or regions/countries.