Platforms for Success in Next Generation IoT Designs

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INTRODUCTION

Over decades, the diverse needs of OEMs fostered the development of a range of different embedded runtime options, from real-time operating systems (RTOSs), to microkernels to Linux, among others. Now, many OEMs are looking towards new technology choices such as virtualization as a mechanism to consolidate previously discrete systems – which often used different operating systems or had different levels of required safety certification. Already, the long-fragmented embedded market is consolidating around fewer technology choices. While still diverse, more and more OEMs are seeing the need to choose third-party technology to help accelerate their development and innovation.

The transition to third-party OS platforms continues to redefine the embedded ecosystem. As OEMs looked at adding more and more smart functionality to their systems, they recognized that they also needed sophisticated OS platforms. In some cases, this meant adding one altogether to systems previously powered by simple kernels or bare metal engines. In others, it meant moving to a third-party solution when they could not scale their own in-house offerings, recognizing a need to focus resources on other stack layers and tap into what the ecosystem had to offer. As more and more OEMs abandon in-house operating systems in favor of third-party solutions, both open source and commercial operating systems have gained favor. However, at a time when OEMs are pressured to both innovate and bring products to market in tight market windows, commercially supported options provide even greater appeal. For projects serving industrial and safety-critical industries, commercial RTOSs are gaining even more traction as more OEMs recognize not only their utility in meeting strict performance requirements, but also their ability to accelerate compliance processes for regulated industries.

Open Source is Here to Stay, But Not Without Challenges

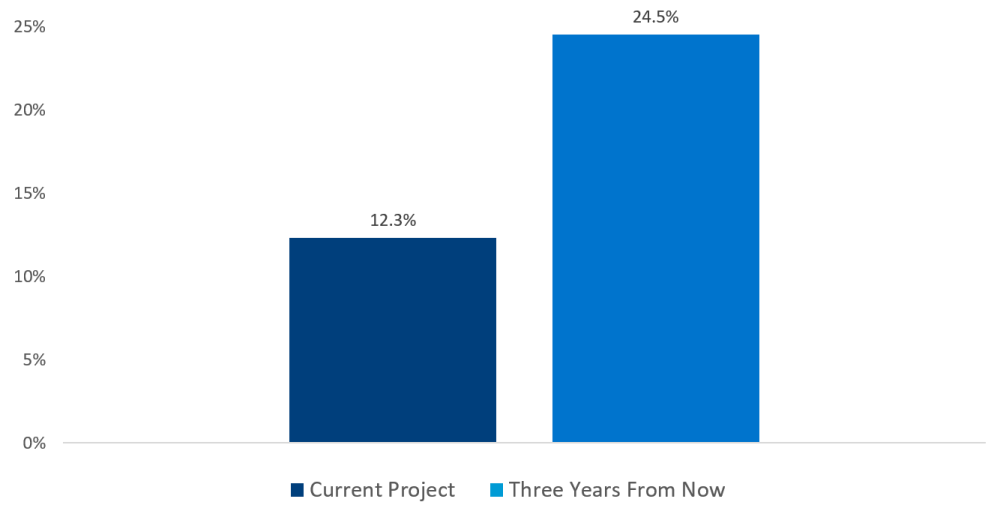
While market dynamics reinforce commercial RTOS's value propositions, many OEMs continue to experiment with Linux and open-source OSs. In fact, Linux has been an active component of the embedded market for two decades. A movement that began focused on networking and communications has gradually expanded to a broad range of industries, including those with both safety-critical and real-time characteristics. In addition to spawning a range of commercial initiatives, Linux-based Android has emerged as another popular runtime choice, offering engineers access to a wide variety of community supported middleware and connectivity stacks and an ecosystem of familiar third-party developers.

Now, given the new set of requirements facing OEMs as they attempt to leverage the IoT, software and OS decisions have become more complex, with no one solution capable of meeting every design's needs. In some cases, on a single SoC, multi-OS deployments now make sense, particularly when safety is an issue and Linux is not an ideal fit. Beyond any more cumbersome asynchronous multiprocessor implementations, organizations must now look for new ways to enable flexible and multi-OS platform choices. The ability to leverage available building blocks and efficiently develop more transferable portfolio IP has never been more important. This strategy – enabled by virtualization – can help promote flexibility, portability, and future reuse across product lines and protect against future, unforeseen R&D costs. Ultimately these changes and concurrent ecosystem moves for standardization have helped engineering organizations balance goals for more capabilities with enhanced flexibility for future designs. Today's embedded design is a complex exercise in which different technologies are now needed to address these new challenges that IoT has introduced. Amid these new IoT market dynamics, it has become clear that while no one solution can solve every engineering challenge, primary OS and hypervisor selection can make a significant impact on both current and future project success.

VIRTUALIZATION PARTITIONING GROWING MARKET NEED

Beyond looking at processors and OSs, there are other technologies showing more and more value to end product designs. In particular, isolation technology is critical to next generation workload enablement. Virtualization has not been widely used in the embedded market historically, but it is nothing new either. Many of the initial use cases revolved around established multiple independent levels of security (MILS) or time and space partitioning. Now, however, the use of virtualization is growing and providing organizations another mechanism to enhance their design flexibility.

Exhibit 1: Virtualization/Hypervisor Use In Current Project
(Percentage of Respondents)



The wide range of virtualization use cases is causing many OEMs to rethink system possibilities and runtime choices. One can consolidate hardware to save on bill of materials, manage multi-OS systems as well as further abstract hardware to promote IP flexibility. As shown in Exhibit 2, application scalability and portability are the top drivers of use as organizations look for ways to proactively manage and protect their engineering assets. Security from partitioning, especially for projects with real-time response requirements, is another valuable use case. For example, military and aerospace systems have long-employed virtualization to create MILS to federate access to sensitive sub-systems and information. Now, avionics certification standards such as DO-178C require such an isolation to allow the verification of individual components without necessitating recertification across all system components – a technology enablement that can save time and money over traditional certification processes.

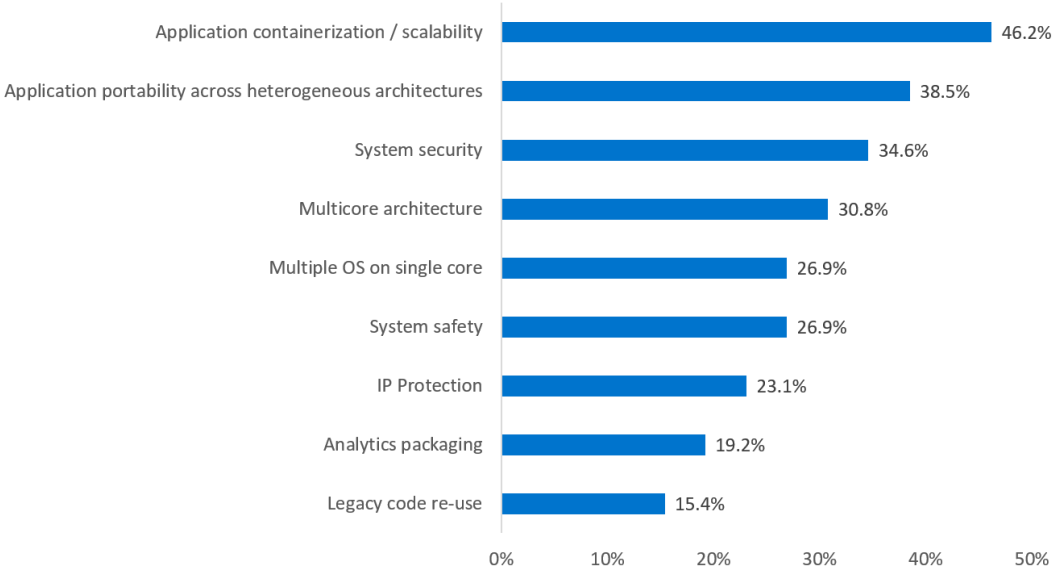
In the automotive sector, many organizations that traditionally lament the addition of any new runtimes are looking at hypervisors as a mechanism to promote system consolidation. Virtualization allows them to reduce the number of electronic control units (ECUs) and save on hardware costs. Some OEMs are looking to consolidate asynchronous data calculations, networking stacks, and real-time systems – and run them on the same piece of hardware. For example, the demand for flexible, software-driven dashboard interfaces is driving the need for hypervisors to manage both sensitive instrument clusters as well as applications controlling user-defined aesthetics and navigation information – that all must be hosted on the same target SoC. Furthermore, the need for a certified operating environment can be efficiently addressed with a safety-certified RTOS and a

safety-certified hypervisor serving as the foundation to satisfy the overarching safety requirements of the system. In other words, a virtualization solution can enable the shift to a more heterogeneous system design approach that facilitates both development flexibility and eased compliance.

Just as for automotive systems, an objective of saving on hardware costs can lead to a need to manage a range of different considerations for industrial automation applications. Virtualization can help accelerate the implementation of these mixed-criticality systems in which plant operators are looking to maintain real-time controller (RTOS-based) fidelity while consolidating with more 'insecure' OS-based systems such as those using Android- or Windows-based Human-Machine Interfaces (HMIs). For example, some organizations may have chosen Windows for its included industrial communications software and application ecosystem but want to leverage proven codes bases and performance for motor drive systems developed with an RTOS, such as the QNX Neutrino RTOS. Even medical systems are looking for similar design flexibility to adapt safety-critical systems to next generation, IoT expectations. For example, one surveyed medical device manufacturer was using a hypervisor to manage diagnostics and updates for a beside monitor interface system. Virtualization allowed the designer to account for both continued monitor function as well as potential interruptions in the interfaces' connectivity.

Exhibit 2: Factors Driving Organizations to Adopt Hypervisor/Virtualization Technology in Current Projects

(Percentage of Respondents)



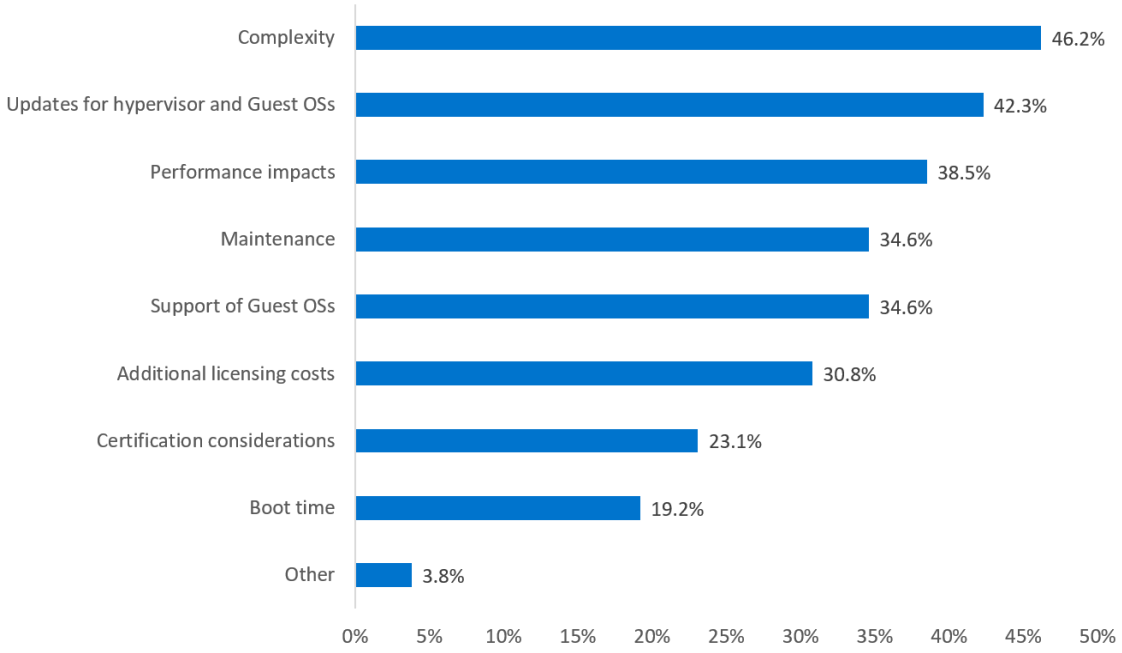
Note: Multiple responses permitted

Virtualization Not without Challenges, Requires Sound Partner Selection

While virtualization can solve problems and enable new system functionality, it also requires an understanding of added the complexity that comes with additional runtime layers, managing peripheral support for functional safety requirements and, at times, performance tradeoffs [See Exhibit 3]. Despite these challenges and potential concerns, 69% of respondents indicated a positive/helpful overall experience with virtualization. To help navigate the issues and determine the best runtime software for a given project's requirements, it is critical that OEMs identify the right partners that can offer the expertise needed for success. Vendors such as BlackBerry QNX have a long track record of reducing design complexity through the use of a microkernel and process isolation. When these same concepts are applied to virtualization, the complexity and update issues of working with guest operating systems are reduced.

Exhibit 3: Top 3 Concerns with Hypervisor Technology

(Percentage of Respondents)

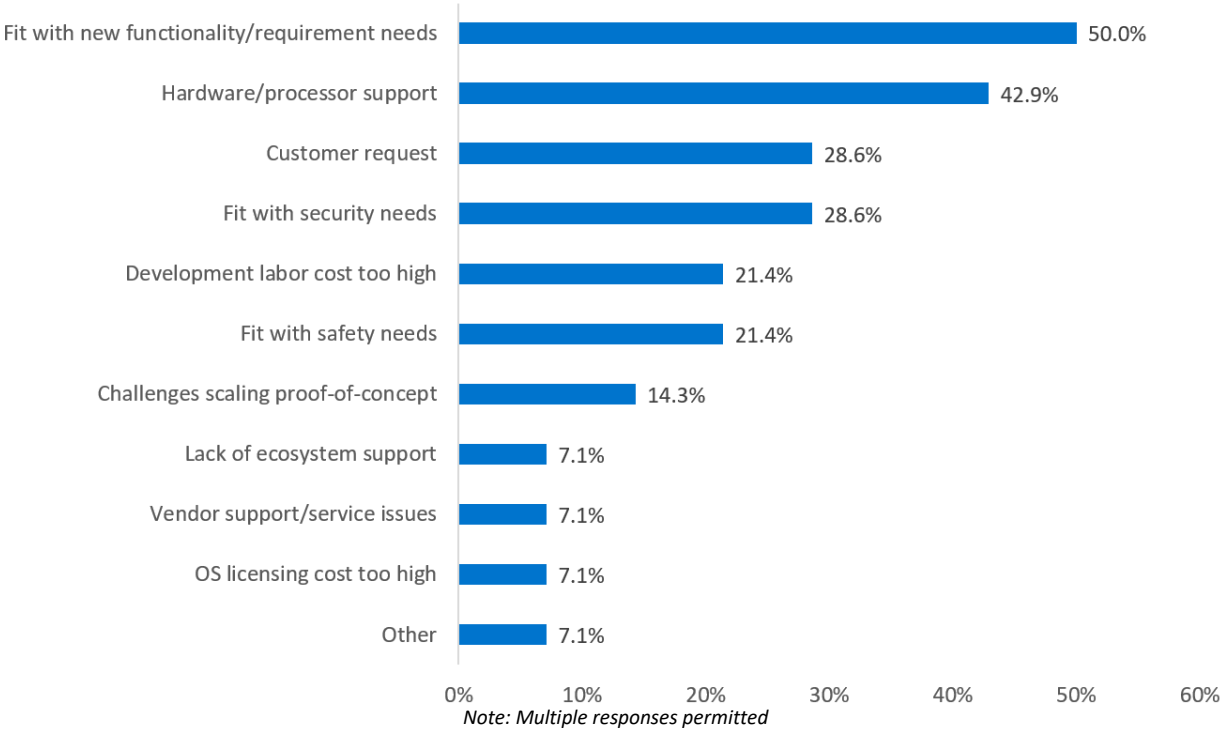


Note: Respondents could each select up to 3 options

The foundation of device functionality remains firmly centered on OS choice. While Linux can be an option for some or part of different OEM system needs, RTOSs are often still the best choice for systems with safety- or security-critical requirements. In many ways, Linux is now such a commonly deployed platform that problems mirror that of the industry overall. The Linux project delays most frequently cited – from complexity of application/tech, complexity of software, and changing requirements – are also identified as the top challenges overall in the research. Looking forward, however, many organizations are recognizing that Linux is not often enough and are considering new primary OSs, with reasons ranging from functionality fits, support, to security needs. With open-source operating systems like Linux, developers must navigate common development challenges and new technology needs on their own. Alternatively, commercial OS suppliers can provide OEMs with a powerful partner, offering access to subject matter experts and experience from many (mission-critical) projects becoming available to its user.

Exhibit 4: Reasons Why Switching From Linux

(Percentage of Respondents)



Note: Multiple responses permitted

Furthermore, one of the traditionally most appealing features of Linux being its openness/flexibility can also be found through other avenues, whether via the use of a hypervisor or the selection of a runtime like that from BlackBerry QNX that offers POSIX compliance for ease of porting as well as a POSIX-based hypervisor environment for supporting Linux guests.

TECHNOLOGY CHOICE CAN DRIVE COST SAVINGS

VDC's Total Cost of Development Calculations

IoT/Embedded market is incredibly complex and heterogeneous. The wide range of features and form factors necessitated across the various embedded vertical markets lead to an equally wide number of variables that drive selection of specific hardware and software components.

Technology selection is influenced not only by current requirements, but also by investments made during past projects whose substitution can lead to additional labor and cost considerations. Given the multivariate evaluations undertaken by engineering organizations when selecting technology, it is important for decision makers to understand as much about a technology's potential impact and return on investment as possible. Despite organization- and project-specific requirements, certain trends and inferences can be drawn when comparing similar projects. While some of these statistics are strongly influenced by industry and/or demographics, some technology choices stood out as having significant effect on project outcomes. One such area was primary operating system choice.

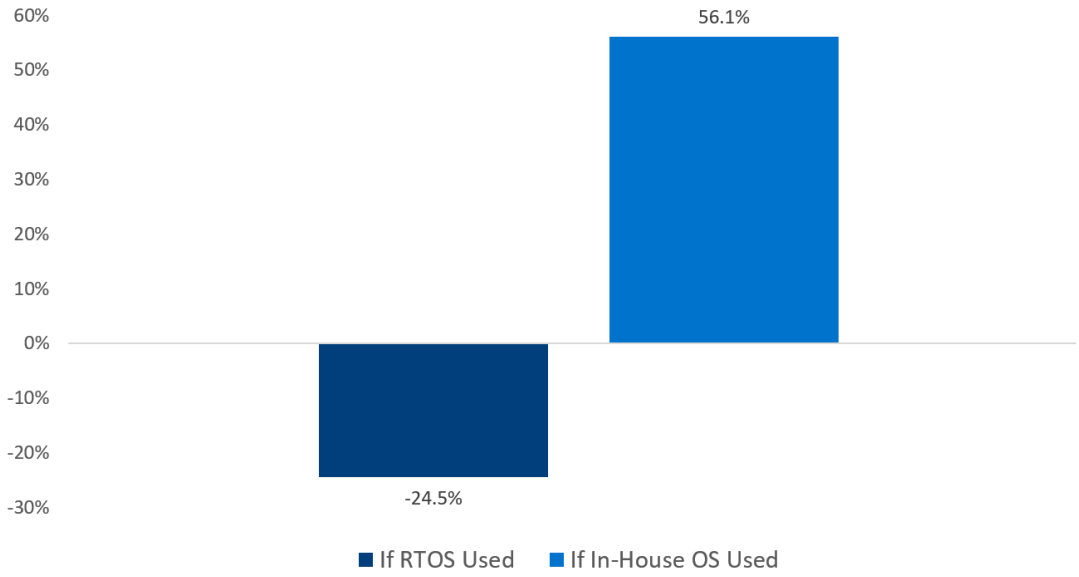
In 2021, VDC completed data collection for a survey commissioned by BlackBerry QNX, with more than 200 respondents from a range of industries. VDC then used those results to create total cost of development calculations, which employ statistics such as: devices per project, Bill of Material costs, distribution of development costs by engineering discipline on current project, number of engineers per project, fully-loaded labor cost average per engineer, project length, product's average years of useful life once deployed in field by the end client, estimated total number of defects or software patches customers report/require per deployed year in field, estimated combined IT and engineering time (hours) required for each patch or defect remediation, and estimated percentage of devices that will become inoperable and require repair or replacement each year. Our comparative cost calculations emphasize the results from projects from the same vertical market, using the same primary operating systems as well as those from projects using the same processor architecture.

While there are a number of factors that can drive organizations to select a particular OS (or multiple OSs) – from memory requirements to in-house expertise to existing software assets – there are many projects when companies could or should have those decisions influenced by total cost of development considerations. Aside from any inherent needs to meet real-time or safety-critical requirements, VDC's research shows that there are often tangible cost and time-to-market savings associated with choosing an RTOS as the primary project OS.

Example Total Cost of Development Calculations Show RTOS-Driven Cost Savings

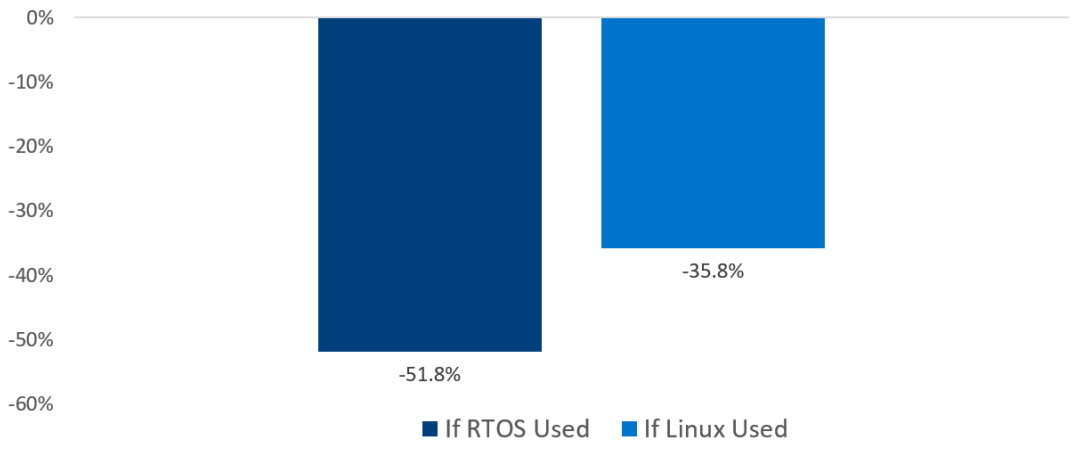
To illustrate the impact of primary operating system choice on total cost of development, we have included a few example scenarios for and outputs from our calculations. The first example evaluates an industrial automation project expected to produce 1,000 units using an ARM-based architecture in which Linux was reported as the primary operating system. According to VDC's calculations, software development costs for a similar project using an RTOS as the primary OS would have been approximately 25% less.

Exhibit 5: Potential Software Development Costs Increase Per Device



Obviously, the results for our calculations vary from vertical to vertical, based on the range of variables and considerations in each sector. For example, outside of a few large OEMs in the space, medical device engineering organizations often adopt new technologies slower and tend to use more in-house technologies in their system builds. Beyond the safety standard certification acceleration benefits that commercial technology can provide, a move to commercial real-time operating systems can also lead to development cost savings. In this next example, an x86-based medical project using an in-house OS and producing 2,500 units could have potentially saved 52% in development costs using a commercial RTOS as its primary OS.

Exhibit 6: Potential Software Development Costs Increase Per Device



SO HOW CAN AN RTOS REDUCE PROJECT COST?

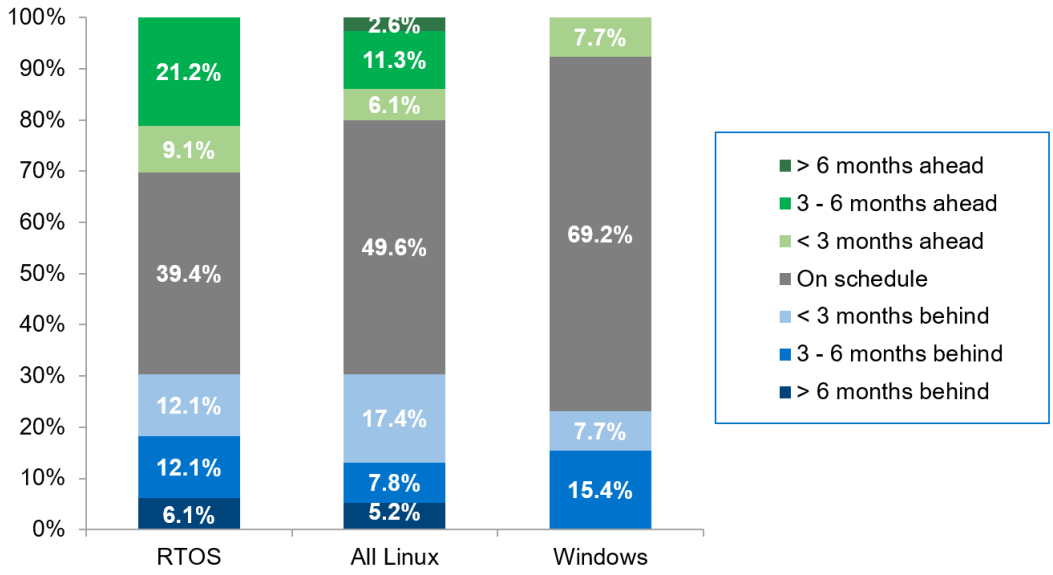
Linux and open-source operating systems are now a fundamental part of the embedded ecosystem fabric, providing a range of quality runtime options to OEMs. However, engineering organizations can often maximize benefit and function for their project when choosing an RTOS to serve as the primary OS – often even alongside Linux in multi-OS deployment using a hypervisor. Commercially supported RTOSs provide not only dependable and deterministic function, but also fewer latent defects that would otherwise consumer internal development time and resources. For example, despite their high rate of use in safety-critical projects – which have development costs more than three-times that of non-safety critical projects – overall averages for total cost of development show RTOS projects generally cost less than Linux alternatives.

As an additional driver of cost savings – engineers using an RTOS as their primary OS report spending a smaller percentage of their project team's total development cost on software development. For years, software gradually encompassed more and more of engineering organization's development budgets, displacing proportional spending on electrical and mechanical component development as more end-product functionality was defined by on-device software. Now, a new vector for differentiation emerged. Cloud/IoT and analytics have become the domain expected to generate the most growth in investment and, ultimately, innovation in the coming years.

With software having become the single largest cost center for engineering organizations, redirecting scarce resources to new value adding areas is critical. This shift allows organizations to focus labor on new areas of differentiation like cloud and analytics functionality. In fact, the developers using an RTOS as their primary OS already report 30% of their product development costs to be related to these areas – a rate much greater than that reported by Linux or Windows users.

The selection or addition of an RTOS makes OEMs more likely to finish projects ahead of schedule. The stability and support available from commercial RTOS vendors as well as the complimentary tools often provided help organizations not only develop efficiently, but also plan more accurately, lowering organizational risk. In fact, projects with an RTOS as the primary OS were 50% more likely than Linux projects to be ahead of schedule. Furthermore, they were actually four times as likely as Windows projects to be ahead of schedule. The benefits of improved schedule adherence extend beyond cost savings, however. IoT service-based business models lead to greater revenue and bottom-line impact from accelerated market entry.

Exhibit 7: Current Projects Schedule
(Percentage of Respondents)



RTOS are not always the right fit. However, individual projects' requirements vary and, for certain applications like gateways, Linux can make more sense than an RTOS when there are fewer deterministic requirements and ample system resources. Additionally, some organizations would prefer higher internal labor and development costs in exchange for more access and control of source code than available from certain RTOS vendors.

VDC'S VIEW

IoT Accelerating Embedded Market Transformation

Clearly, the issues and goals in the embedded engineering space today are forcing OEMs to adapt. The requirements of product functionality today require new approaches to runtime selection. In some instances, product designers are evaluating the benefits of system consolidation, which, in turn, brings in new considerations around multi-OS and mixed-criticality system architectures that must also be managed. More than ever, OEMs need to look for new, third-party technologies to accelerate time-to-market and enable their differentiation. Ultimately, we see the adoption of more standard technology platforms to enable that end goal, whether that be through an OS like Linux, an RTOS, or even the combination of the two with a hypervisor. Given the rapidly evolving and multivariate consideration set, engineers want and need an ecosystem of easily integrable solutions to accelerate development.

New Premium on Strategies to Accelerate Time-to-Market and Differentiation

More than ever, OEMs need to look for new technologies to accelerate time-to-market and enable their differentiation. At times, an organization has the flexibility to choose a runtime that can save time or cost over other options. In others, functionality or project requirement needs dictate a certain choice. In still others, more OEMs are recognizing the utility of virtualization and multi-OS systems. Solutions such as the QNX Hypervisor let proprietary, open source, Linux and Android OSs work in parallel, sharing the same hardware and resources. With a solution built on the standard VIRTIO interface, this approach can enable complex sharing and abstraction of underlying hardware such as the graphics, audio, video and USB devices required to combine functions for digital cockpits, domain controllers and other multi-purpose SoC platforms.

Critical to Choose a Partner for Today and Tomorrow

At a time of unparalleled change in the embedded ecosystem, organizations need to not only find a flexible suite of technology, but they must also look for commercial partners that can offer the expertise needed to adapt at scale. This charter becomes even more critical in the context of safety- and security-critical device classes, especially given the increasing implementation of mixed-criticality environments. Furthermore, our research has shown that primary OS solution selection can have a significant impact on project outcomes, saving both development cost and time to market. Choosing a commercial RTOS that offers both the ability to address safety and real-time requirements while also supporting design flexibility and the open-source ecosystem via a hypervisor can position an OEM for success, both now and in the future.

As such, it is becoming increasingly important to choose partners like BlackBerry QNX that can also support open-source, Linux and Android and have extensive experience helping customers implement mixed software environments to ensure that various components interoperate safely and securely. To this end, BlackBerry QNX virtualization solutions use functionally safe, pre-certified virtual machines to underpin the management of the varied operating systems that are required to run today's software-defined vehicles and next-generation IoT devices. Not only can organizations achieve design flexibility and cost savings with BlackBerry QNX's hypervisor and RTOS, but access to their vast experience and subject matter experts can help OEMs navigate new challenges and speed time to market.

ABOUT VDC RESEARCH

Founded in 1971, VDC Research provides in-depth insights to technology vendors, end users, and investors across the globe. As a market research and consulting firm, VDC's coverage of AutoID, enterprise mobility, industrial automation, and IoT and embedded technologies is among the most advanced in the industry, helping our clients make critical decisions with confidence. Offering syndicated reports and custom consultation, our methodologies consistently provide accurate forecasts and unmatched thought leadership for deeply technical markets. Located in Natick, Massachusetts, VDC prides itself on its close personal relationships with clients, delivering an attention to detail and a unique perspective that is second to none.

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