

Tech-Clarity

making the value of technology clear

Tech-Clarity Perspective: Developing Software-Intensive Products

***Addressing the Innovation –
Complexity Conundrum***



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Executive Overview

Manufacturers today face a strategic conflict as they develop products that derive a significant amount of functionality and innovation from software. On the one hand, software dramatically improves product innovation, increases product capabilities, and provides other important strategic benefits ranging from competitive market advantages to cost savings. These benefits are compelling, as described in Tech-Clarity's Systems & Software Driven Innovation: Complexity and Opportunity in the Mechatronic Era. On the other hand, product developers face increased complexity that can lead to poor quality, longer product development cycles, and reduced efficiency. Tech-Clarity surveyed over 100 companies to understand how manufacturers can take advantage of the benefits of a software-intensive product strategy without suffering from the inherent complexity.

Strategies to achieve greater product capabilities, smarter products, and increased innovation drive the need to include more software in products.

The study results underscore the importance of addressing this innovation-complexity conundrum. The majority of companies significantly increased the *amount* of software, the *importance* of software, and the *innovation driven by software* in their products over the last five years – and plan to increase these further over the next five years. Why? The simple answer is better products. Survey respondents across industries confirmed this, indicating that strategies to achieve greater product capabilities, smarter products, and increased innovation drive the need to include more software in products.

The survey also uncovered significant challenges and negative business impacts resulting from complexity. For example, over one-half of the companies surveyed indicate they experience product quality issues and delayed time to market when developing software-intensive products. How can manufacturers enjoy the benefits of a software-driven product strategy without falling into the quality and time to market traps due to complexity? The survey identified that companies with the following characteristics reported fewer significant, negative impacts when engineering products that include electrical, mechanical, and software components:

- Unified or integrated teams for electrical, mechanical, software engineering
- Use of systems modeling
- Unified or integrated solutions for designing software-intensive products
- Use of formal data / lifecycle management solutions (ALM and/or PLM)

Tech-Clarity's conclusion from this report is a Product Lifecycle Management (PLM) approach is well positioned to enhance collaboration and integrate processes, teams, and technology to relieve manufacturers from the challenges and impacts inherent in developing software-intensive products.

Increased Prevalence and Importance of Product Software

Tech-Clarity investigated the usage trends and changing importance of software in products over the past five years. Perhaps not surprisingly, the use of software in products has increased significantly over the last five years (Figure 1). This trend is also accompanied by an increased ratio of software engineers versus others, such as mechanical or electrical engineers. As André Radon, VP IT Competence Center Engineering Applications for tier 1 automotive supplier Continental says, *“We are actually a software company. The majority of our engineers are software engineers.”*

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André Radon, VP IT Competence Center Engineering Applications, Continental

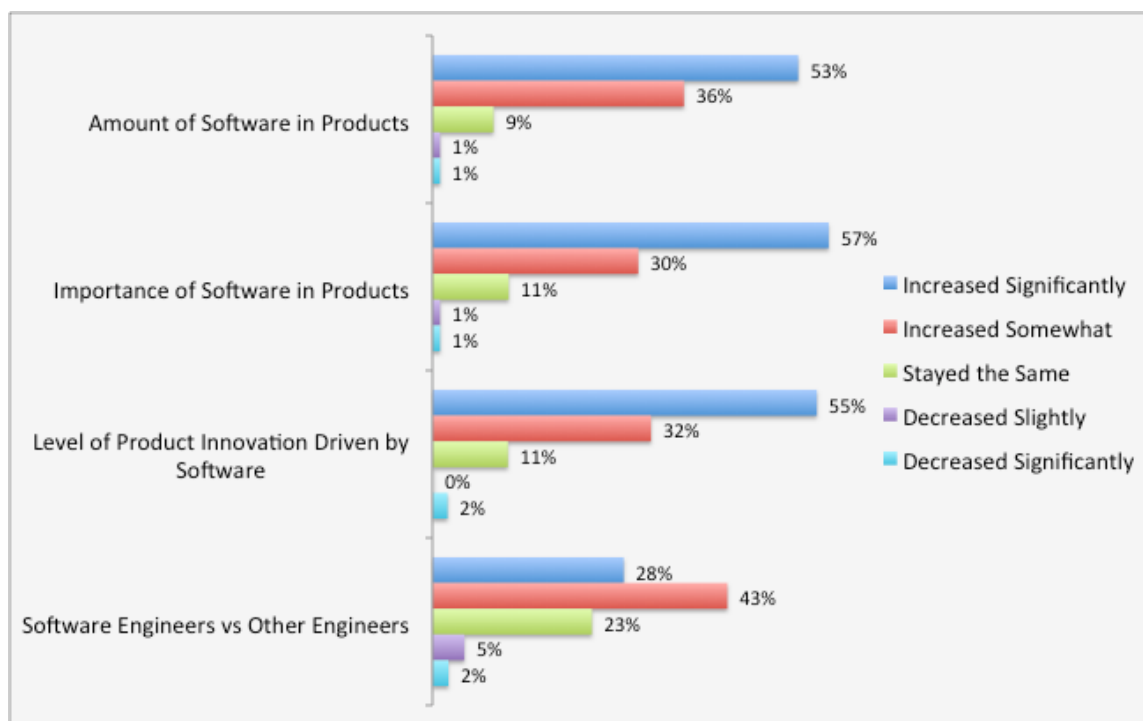


Figure 1: Change in Product Software over Past 5 Years

Perhaps more important than the increased *use* of software in products is the fact that the *importance* of software in products and the *level of product innovation driven by software* have also increased significantly. This supports the conclusions of the Systems & Software Driven Innovation report, which highlights how software-intensive product strategies help companies innovate. *“Some people say 60% of innovation in a car is*

software and others say 90%,” explains André Radon of Continental. “I am not sure which is true, but it is a high percentage.”

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These survey results indicate a significant trend. The majority of companies have increased significantly in every measure related to the use of software in products. In fact, very few companies (between 1% and 2%) stated that the amount, importance, or innovation from software decreased over the past five years. The trend can be observed in big and small companies alike, and across manufacturing industries. The biggest increases in the level of software and amount of innovation driven by software were found in automotive and high-tech industries, while automotive was clearly the highest for importance of software. Interestingly, the life sciences industry (which includes medical device manufacturing) has increased the ratio of software engineers more than others, and 92% of respondents in that industry say they plan to further increase software use over the next five years.

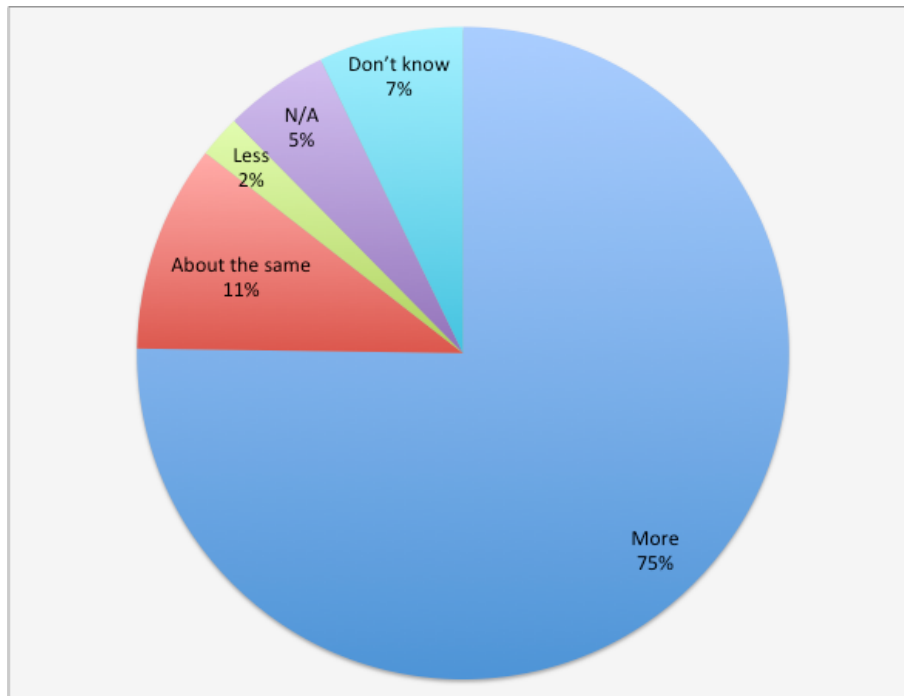


Figure 2: Plans for Level of Software in Products over Next 5 Years

Life sciences companies are not alone in their plans to expand the use of product software. In fact, three-quarters of all companies surveyed say they plan to include more software in their products over the next five years (Figure 2). Only 11% say they plan to keep the levels about the same, and only 2% said they plan to include less. Clearly there is no reversal expected in the trend towards increased use of software in products.

Three-quarters of all companies surveyed say they plan to include more software in their products over the next five.

Adopt a Software-Intensive Product Strategy

What is the reason behind the trend towards more product software? Software-intensive product strategies enable important product strategies and create significant opportunities. As Systems & Software Driven Innovation Report concludes, “*Software development is moving from an afterthought to a core component of product innovation.*” As the report explains, leading companies will look to take advantage of software driven innovation to improve their ability to:

- Tailor products
- Increase reuse
- Make agile updates to products in the field
- Reduce product cost
- Lower product development cost

The top reasons companies are pursuing software-intensive products are competitive factors that drive the top line.

The survey results support the fact that software-intensive products are, quite simply, about designing better products, faster, at lower cost. The first thing to notice from the survey results is that there are a lot of reasons that companies are increasing the use of product software (Figure 3). About three-quarters (74%) indicate they use software in their products to improve product capabilities. About two-thirds (68% and 62% respectively) say they are seeking "smarter" and more innovate products. About one-half (49%) say they use software to tailor products to customers or markets. The top reasons companies are pursuing software-intensive products are competitive factors that drive the top line.

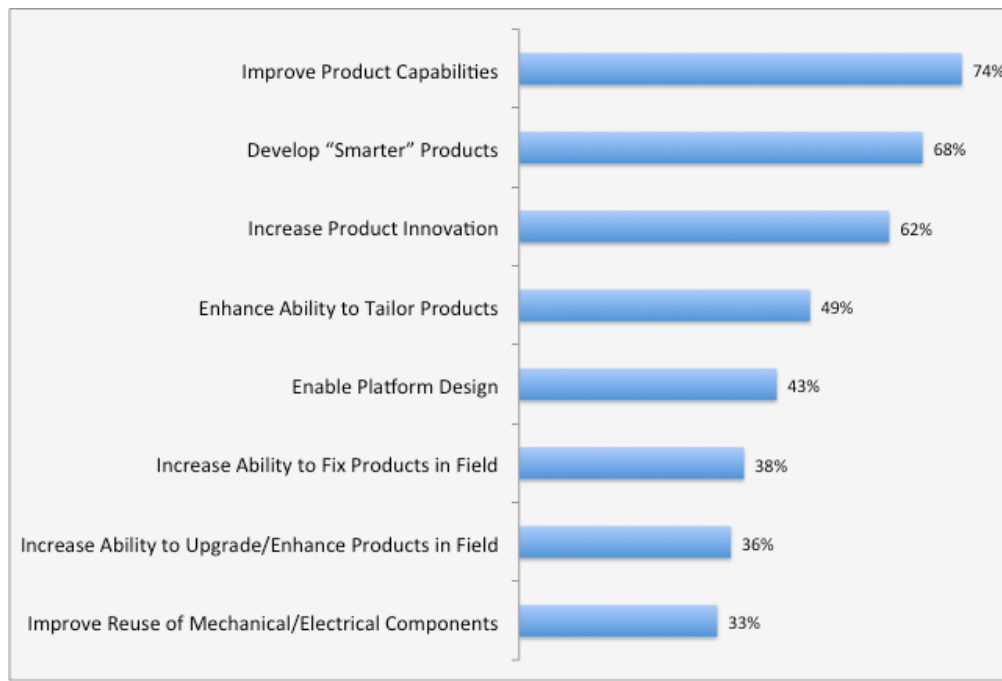


Figure 3: Product Strategies Driving Use of Software in Products

But top line improvements are only part of the story – manufacturers are increasing the level of software in their products to drive higher levels of product profitability. Other strategic benefits include platform design (43%) and reuse (33%), which can reduce cost and development time to improve the bottom line. In addition, over one-third say they are looking for advantages in the service lifecycle including the ability to fix, upgrade, or enhance their products after they are released and in the market. This is a significant opportunity for companies to leverage software-driven product functionality. *“If you experience a problem in the field it is usually mechanical and sometimes electrical, but software is almost always the most flexible and the cheapest way to correct it,”* offers Continental’s André Radon.

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Of course not all software-intensive product strategies are alike. In fact, the most common strategies varied by industry (Table 1).

Industry	Product Strategy
Aerospace & Defense	Develop “smarter” products (92%) Increase product innovation (75%) Improve product capabilities (75%)
Automotive & Transportation	Improve product capabilities (85%) Enable platform design (54%) Improve reuse of components (54%)
High Tech & Electronics	Improve product capabilities (94%) Develop “smarter” products (94%) Increase product innovation (75%) Increase Ability to Upgrade/Enhance in Field (63%) Increase Ability to Fix in Field (56%)
Life Sciences	Improve product capabilities (85%) Develop “smarter” products (69%) Increase product innovation (54%) Increase Ability to Upgrade/Enhance in Field (54%) Enable platform design (54%)
Machinery & Industrial	Increase product innovation (92%) Improve product capabilities (92%) Develop “smarter” products (92%) Enhance ability to tailor products (67%) Enable platform design (58%)

Table 1: Top Product Strategies Driving Software Use in Products by Industry

Understand Challenges and the Resulting Business Impacts

Despite the potential benefits, software-intensive product strategies come with a price. As Tech-Clarity’s Five Dimensions of Product Complexity reports, including more software in products increases product and product development complexity. Survey responses confirm this, identifying quite a few significant challenges that manufacturers face when developing software-intensive products (Figure 4).

“We have to be responsive to change, but managing risk is a key issue because one component team has dependencies on another team.”

Joachim Maes, Director of Process Engineering, TomTom

One of the key issues is keeping everything coordinated when designs change. In fact, over one-half (56%) of survey respondents report that managing change is a significant challenge when developing software-intensive products. “*Managing dependencies when a change is introduced is one of the hardest things to do,*” says in-car location and

navigation provider TomTom's Director of Process Engineering, Joachim Maes. *"We have to be responsive to change, but managing risk is a key issue because one component team has dependencies on another team."* Continental also faces challenges and complexity from change management. *"We can support different applications in different products with the same software by using different configurations,"* says Continental's Radon. *"It drives complexity because if you change the platform it might impact 200 systems, and the impact might be different."*

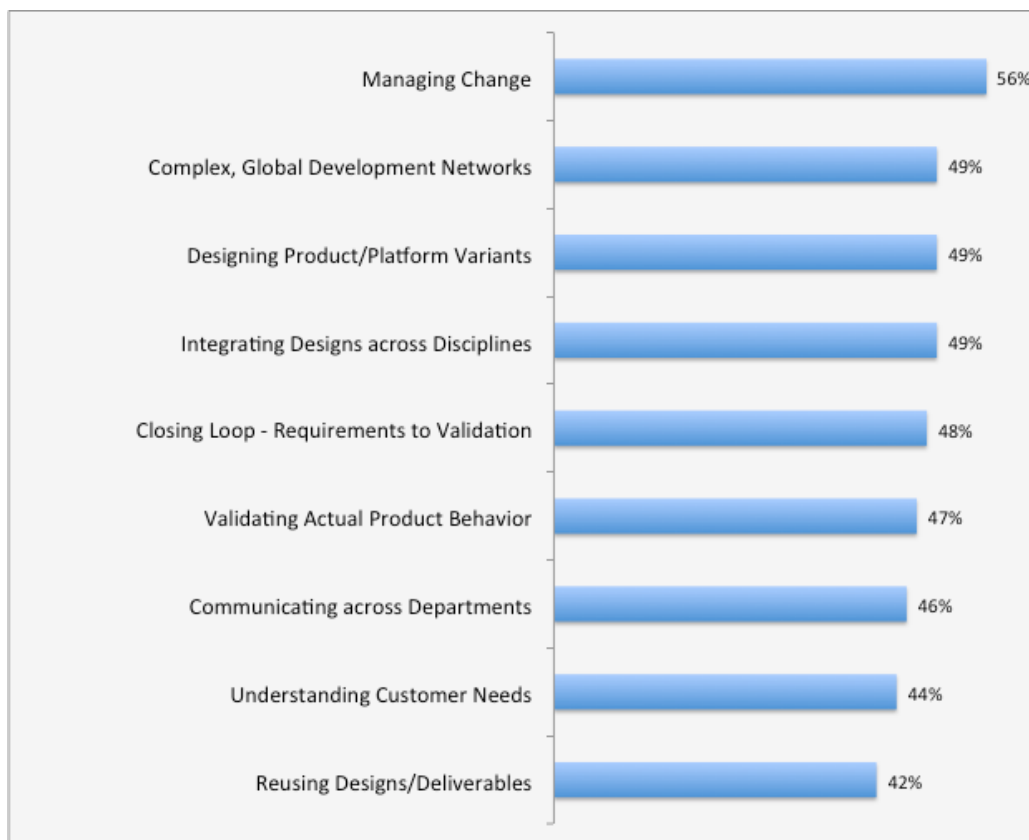


Figure 4: Challenges Developing Software-Intensive Products

Change management is only one of many challenges companies face when developing software-intensive products.

Managing change in any software environment is a challenge, let alone when it has to be coordinated with changes in mechanical and electrical designs. But change management is only one of many challenges companies face when developing software-intensive products. About one-half of survey respondents report managing product design environments that are spread out across the world (global design networks), designing for

variants, integrating across disciplines, and closing the loop from requirements to validation as issues. Almost one-half of companies report testing / validation and communication across departments as issues. In addition, they still face common product development challenges such as understanding customer needs and reuse (still very prevalent at 44% and 42%).

Quality problems from software are particularly distressing given that software-intensive products are very prevalent (and growing) in industries that produce safety-critical products.

These challenges must be addressed in order to avoid significant, negative business impacts (Figure 5) that can undercut the benefits of a great product strategy. Over one-half (58%) of companies experience product quality issues. For example, “*Many failures in cars are counted as electrical problems, but a high percentage of those are software problems,*” points out André Radon. Quality problems from software are particularly distressing given that software-intensive products are very prevalent (and growing) in industries that produce safety-critical products. Regulated industries such as Automotive, Aerospace, and Medical Devices must comply with rigorous safety regulations and cannot accept the same level of defects commonly found in business applications.

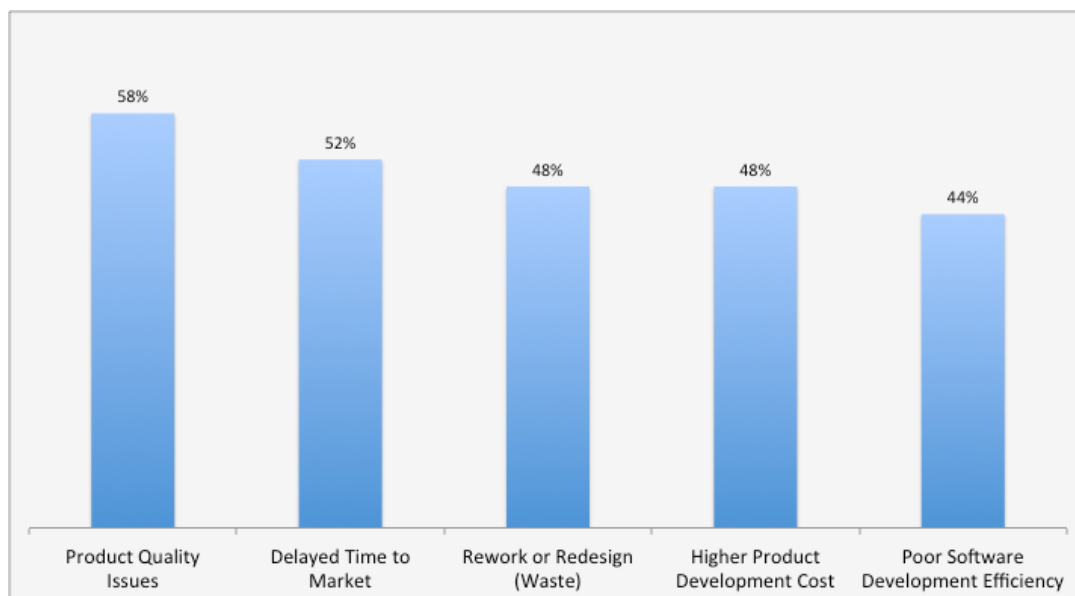


Figure 5: Negative Business Impacts Developing Software-Intensive Products

Quality is an important issue, but it is only one of a number of significant business impacts experienced when developing software-intensive products. Ironically, reuse and

platform design are benefits companies seek (as reported previously in Figure 4) and can lead to faster time to market. But these benefits could easily be offset by complexity, as over one-half (52%) of survey respondents report delayed time to market when developing software-intensive products. In addition, about one-half (48% each) report impacts of rework and higher product development cost for software-intensive products, and 44% indicate poor software development efficiency. Clearly these impacts have to be addressed because quality, time, and cost are very important drivers of market success and product profitability.

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Some might think that smaller companies are immune to these issues. The results, however, indicate the opposite. Manufacturers with annual revenue of less than 250 million dollars (or US dollar equivalent) have roughly the same challenges, but are impacted more significantly. Of these smaller companies, 80% say they have product quality issues, almost three-quarters (73%) say they have rework or redesign (waste), and over one-half (60%) suffer from delayed time to market and higher product development cost. Clearly this is an issue for big and small companies alike. And for those that think these issues are only relevant to a limited number of industries, the issues reported were remarkably similar across industries. So what factors influence the impacts companies experience? The next sections of the report will compare the organizational, process, and enablement approaches with the reported impacts to help determine which approaches best address the challenges faced when developing software-intensive products.

Organize for Success

One of the characteristics that correlated with lower business impacts was team structure. As stated earlier, about half of the responding companies indicate being challenged by operating in globally distributed design networks. How can they communicate and collaborate effectively across this extended supply chain? Very few companies (only 16%) report having a unified team. This is not surprising given that most companies operate in supply chains that are not vertically integrated. About one-half of companies (51%) report that they have integrated but separate teams for mechanical, electrical, and software engineering.

A more integrated team structure helps manufacturers avoid the most common impacts of developing software-intensive products.

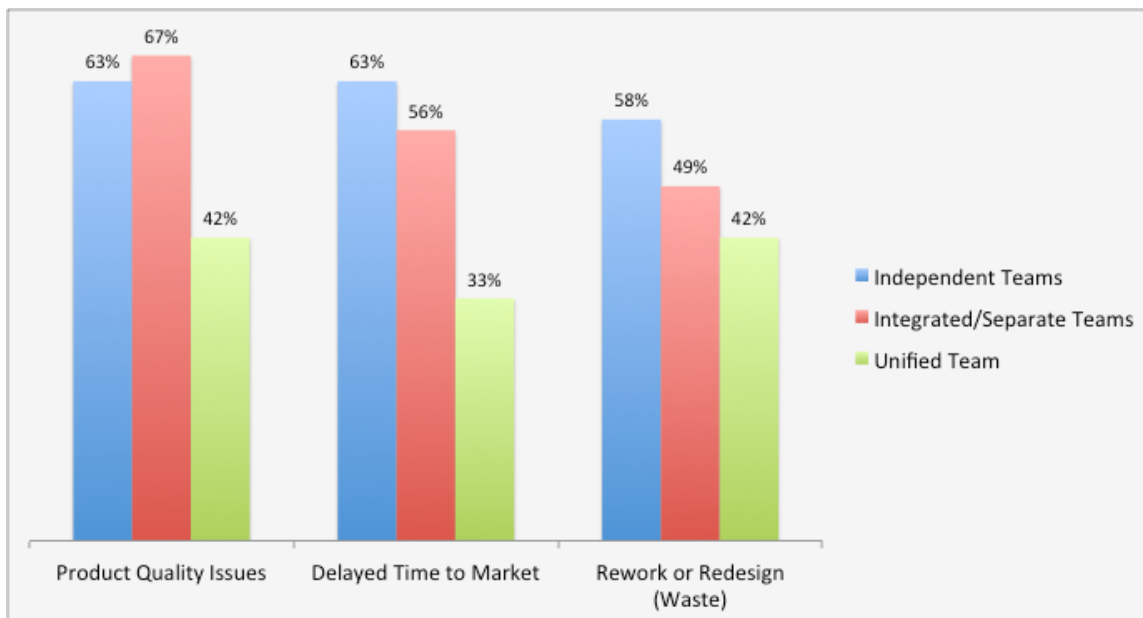


Figure 6: Negative Impacts Developing SW-Intensive Products by Team Structure

The most interesting finding about organizational structure is that certain team structures encounter negative impacts less frequently than others (Figure 6). This leads to the conclusion that a more integrated team structure helps manufacturers avoid the most common impacts of developing software-intensive products. Independent teams likely do not communicate and collaborate as well, leading to surprises, late changes, and integration issues that impact quality, time, and cost.

Joachim Maes of TomTom explains the benefits of an integrated team. *“Our cross-functional teams clarify requirements and make sure they are achieved by the different program areas,”* he says. It is also more likely that integrated teams share common processes in order to allow different disciplines to deliver on different aspects of the product. Continental standardized on tools as well as processes, according to André Radon. *“We realized we had to standardize software development processes (and tools) because we will have more projects that require us to cooperate across our business units,”* he says.

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Look at the Big Picture

Another company characteristic that corresponded to frequency of negative impacts was the use of systems modeling (Figure 7). Systems models help companies develop a comprehensive plan of attack to meet product requirements, and help them understand product behavior across design disciplines. Of the companies surveyed, however, only 12% consistently create systems models. Of course not all products might deserve a systems model. About one-half of companies (51%) report that they sometimes create systems models.

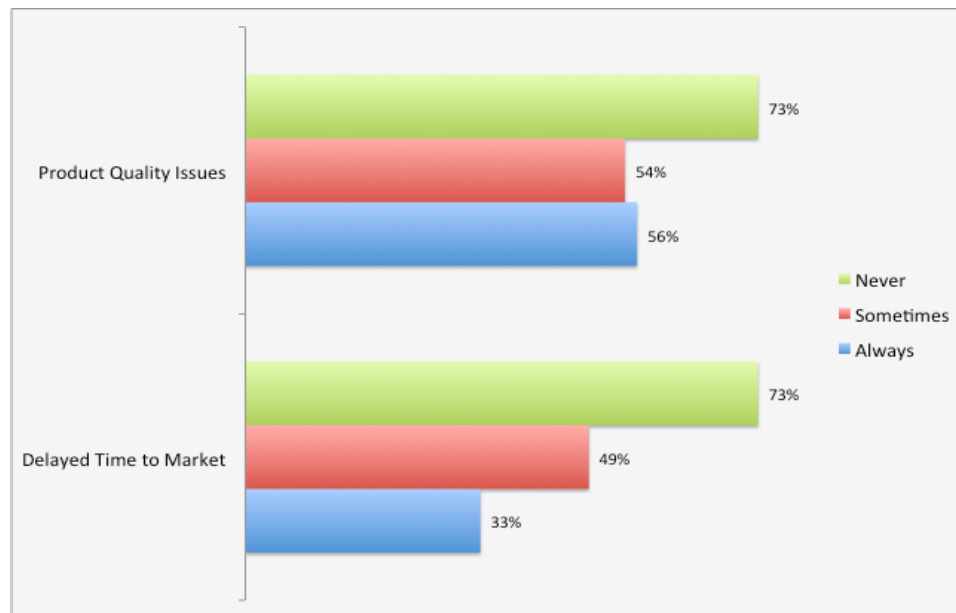


Figure 7: Top Two Negative Impacts by Use of Systems Models

The analysis identified an inverse relationship between how frequently companies experience the top negative impacts (quality and time to market) and whether they develop systems models. For example, companies that never develop systems models experience more rework or redesign waste than either those that always or sometimes develop systems models. In addition, those that develop systems models at least sometimes are much less likely to suffer from poor efficiency compared to those that never develop them. This indicates that systems modeling helps companies avoid product quality and time to market issues.

Systems modeling helps companies avoid product quality and time to market issues.

Systems modeling allows companies to get the system architecture right early in the product development process, helping avoid late changes. Systems modeling starts with a solid understanding of requirements which then cascades through a holistic view linking requirements through validation and verification. “*You need to understand the impact of components on each other, a change in one thing has impacts on others,*” explains Continental’s André Radon. “*You have to think in systems instead of components.*” This helps companies proactively design and manage interactions between mechanical, electrical, and software components.

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Take an Integrated Approach to Enablement

In addition to organization and process, the research investigated the use of software technology in product design and development. The survey analyzed the positive impacts companies reported from using technology to support development (Figure 8). The research shows that enabling software tools provides strategic benefits, and are effective at addressing the biggest negative impacts companies face when developing software-intensive products.

***Enabling software tools provides strategic benefits,
and are effective at addressing the biggest negative impacts companies face
when developing software-intensive products.***

About one-half (49%) of companies indicate that software solutions have improved product quality. Product quality is the biggest problem companies have reported, and the one that appears to be the most significantly addressed by enabling technology. “*We have seen significant improvements in product development efficiency as well as improvements in warranty claims,*” says André Radon of Continental’s use of enabling solutions. “*It has a real bottom line effect.*”

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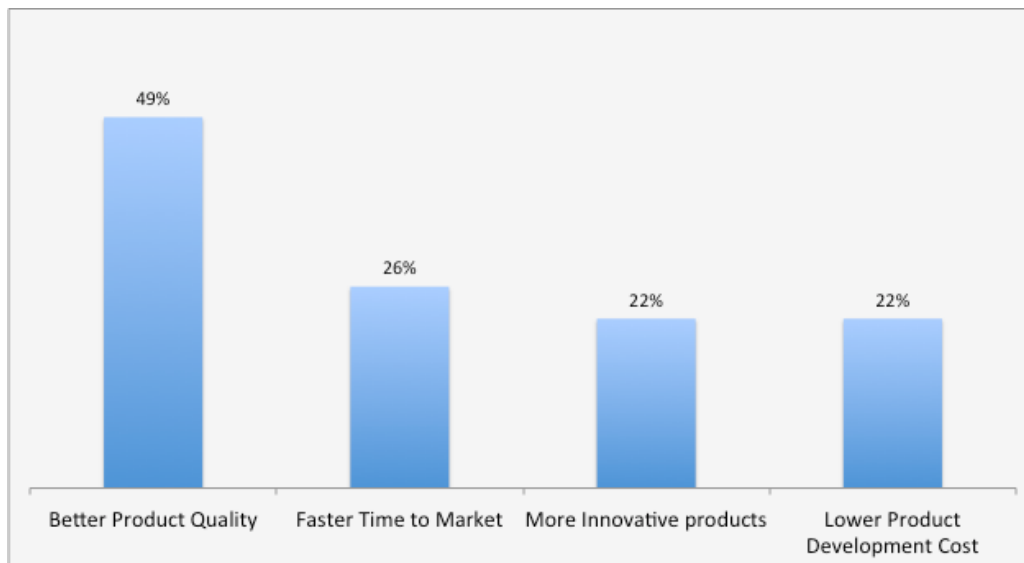


Figure 8: Benefits of Enabling Software to Designing SW-Intensive Products

In addition to improving quality, about one-quarter of manufacturers (26%, 22%, and 22% respectively) report software has improved time to market, helped them develop more innovative products, and reduced product development cost. The survey results show that benefits of using software technology are well suited to counteract the business impacts that plague companies with software-intensive products. *“When we didn’t have the software, it was very difficult to make decisions because you need a full view of what is going on,”* comments Veerle Hostyn, Senior Manager Planning Office for TomTom. *“Now that we can see, we make much better decisions and in the overall picture, we save time and money.”* Enterprise-level systems help companies enable integrated teams and address the full systems lifecycle, allowing them to collaborate more effectively across their cross-functional teams inside and outside of the organization.

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Another aspect of enabling technology analyzed was the level of integration of tools used to design products with mechanical, electrical, and software components. Integration offers the potential to provide a transparent view of the product lifecycle, offering a single version of the truth that spans lifecycle, disciplines, and roles. About one-half (54%) of companies claim to have integrated but separate solutions for design, while about one-quarter report disconnected point solutions. Only 11%, not surprisingly, have a

single system. Because there was no formal definition of “integrated” in the survey it is likely that the number of companies with well-integrated solution is even lower than reported.

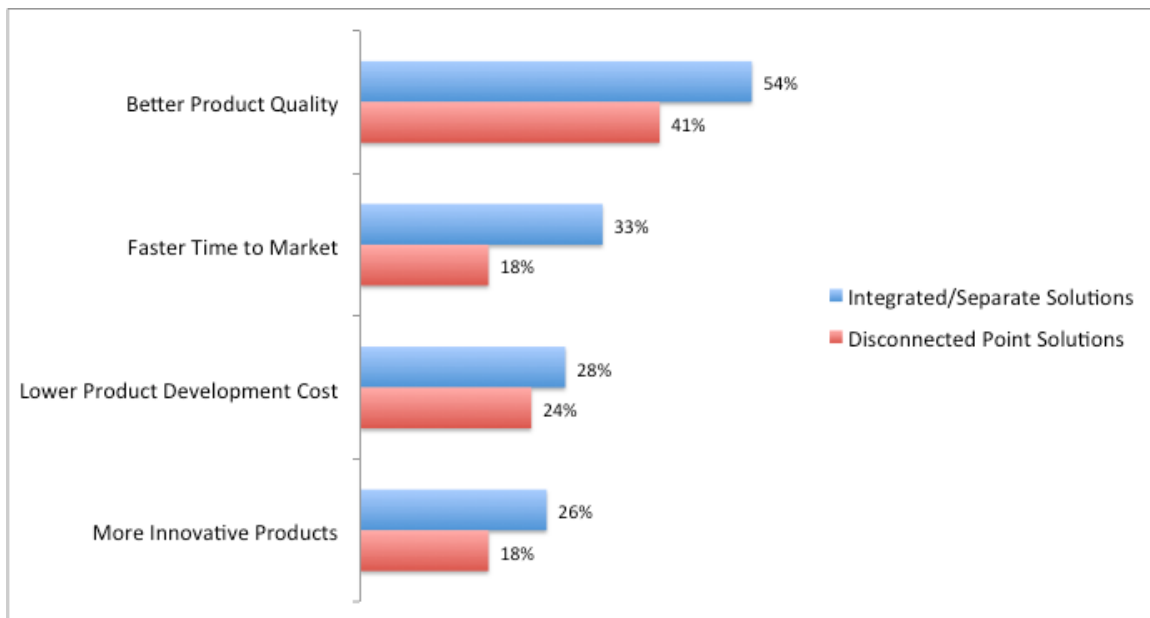


Figure 9: Benefits of Enabling Software by Technology Integration

Companies with disconnected point solutions are more likely to experience the most frequent negative impacts than those with integrated solutions or a single system.

The research shows a correlation between integration and performance. Companies with disconnected point solutions are more likely to experience the most frequent negative impacts than those with integrated solutions or a single system (Figure 9). Systems are helpful, and integrated solutions are even more helpful. “*We have an integrated environment that maintains links between all of our information and documents from requirements until the product is released to production,*” describes André Radon of Continental. “*If you pull out a test it has the configuration, variant, status of change documents, and requirements that led to it. It’s a big, big advantage.*” Not surprisingly, companies with integrated systems are also more likely to report the important benefits systems can offer than those with disconnected point solutions.

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André Radon, VP IT Competence Center Engineering Applications, Continental

The type of solution used to manage mechanical, electrical, and software designs also makes a difference. The lowest frequency of negative impacts appears to be in companies using a structure lifecycle management approach, consisting of Product Data Management (PDM), Product Lifecycle Management (PLM), or Application Lifecycle Management (ALM). Companies that used general document management or shared folders did not fare as well. The same is true for the benefits (Figure 10), where companies that took a structured lifecycle approach reported benefits more frequently. *“Tracking requirements, deliverables, and status is very important,”* says Veerle Hostyn, Senior Manager Planning Office for TomTom. *“With people all over the world and in different time zones, we can’t rely on the phone to see where they are in the lifecycle or whether we can start testing.”*

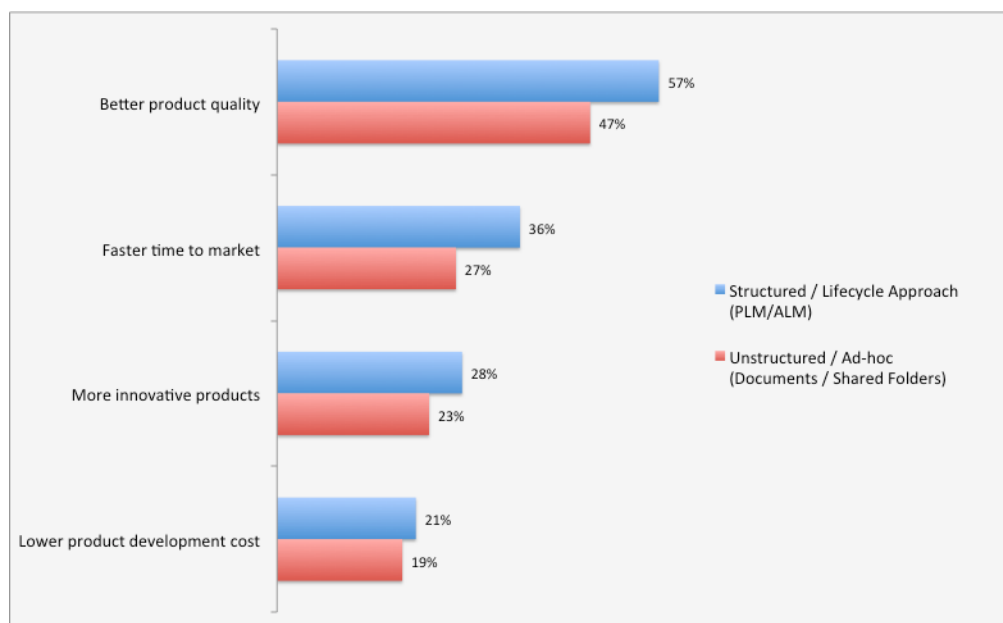


Figure 10: Benefits of Enabling Software by Technology Approach

A structured, integrated approach reduces impacts and drives higher levels of benefit. Adopting a lifecycle approach provides context to decisions, associativity, traceability, and allows companies to manage the entire development process from the requirements to validation and verification. *“Our core platform is very important for traceability,”* says

Joachim Maes of TomTom. *“We have visibility from our business requirements all the way down to deliverables. Without it, we would be much more error prone.”*

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Tech-Clarity’s The Five Dimensions of Product Complexity put forward a concept called the “four degrees of PLM expansion.” The expansion of PLM covers a broader array of processes, more people, a richer view of the product, and more complete view of the product lifecycle. This expansion is highly beneficial to developing software-intensive products. As Continental’s André Radon explains, *“The goal of our multidisciplinary PLM architecture is to have a common tool for all engineering disciplines – mechanical, electrical, software, and systems – for all process from requirements to test and production release.”* Mr. Radon further pointed out that Continental already has the complete process for software development.

Conclusion

The survey results clearly indicate that companies are increasing their adoption of software-intensive product strategies. The prevalence of software has increased in both usage and importance and shows no sign of slowing down, leading to new opportunities and challenges. Developing software-intensive products presents a conundrum for manufacturers, enabling strategic business benefits while simultaneously increasing product and product development complexity. The benefits are too important to ignore, so the impacts of complexity must be mitigated.

Leading companies have more integrated teams, are more likely to employ systems modeling, leverage integrated design solutions, and take a lifecycle approach to supporting systems-driven product development.

The survey results also indicate that some companies are experiencing fewer negative impacts than others, despite facing the same challenges. The higher performing companies tended to take different approaches to organization structure, systems modeling, and enabling technology. Specifically, leading companies have more integrated teams, are more likely to employ systems modeling, leverage integrated design solutions, and take a lifecycle approach to supporting systems-driven product development.

“Our development system especially helps improve quality and consistency.”

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Companies that leverage enabling technologies are gaining important business benefits, including improved quality and faster time to market. *“Our development system especially helps improve quality and consistency,”* explains Joachim Maes of TomTom. *“Pure efficiency is there as well, but it’s harder to quantify.”* The expansion of PLM solutions offers a significant opportunity to integrate teams, improve collaboration, and provide a transparent view of product development across the supply chain and product lifecycle. *“To take a systematic approach, you have to have a system that supports all processes across the whole organization,”* suggests Continentals André Radon. *“You need an integrated solution.”* Manufacturers that adopt a structured data / lifecycle approach are more likely to achieve these valuable benefits.

Recommendations

Based on industry experience and research for this report, Tech-Clarity offers the following recommendations:

- Adopt an integrated or unified team structure to develop products with mechanical, electrical, and software components
- Leverage systems modeling techniques to get systems architecture right up front
- Integrate design and development solutions across engineering and product development disciplines
- Take a product lifecycle management approach, enabled by structured, integrated software technology such as PLM

About the Author

Jim Brown is the President of Tech-Clarity, an independent research and consulting firm that specializes in analyzing the true business value of software technology and services. Jim has over 20 years of experience in software for the manufacturing industries, with a broad background including roles in industry, management consulting, the software industry, and research. His experience spans enterprise applications including PLM, ERP, quality management, service, manufacturing, and others. Jim is passionate about improving product innovation, product development, and engineering performance through the use of software technology and social computing techniques.

Jim is an experienced researcher, author, and public speaker and enjoys the opportunity to speak at conferences or anywhere that he can engage with people that are passionate about improving business performance through software technology.

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About the Research

Tech-Clarity gathered over 100 responses to a web-based survey on designing software-intensive products. Survey respondents were recruited through direct e-mail and social media by Tech-Clarity and PTC. Tech-Clarity also interviewed leaders from two leading companies in order to share their software development experience and knowledge.

The respondents were comprised of about one-half (49%) who were individual contributors. Another one-third (34%) were manager or director level, and the remainder included internal consultants (12%), and others. There was very little representation from VP or executive levels.

The respondents represented a mix of company sizes, including 23% from smaller companies (less than \$250 million), 8% between \$250 million and \$1 billion, 19% between \$1 billion and \$5 billion, and 19% greater than \$5 billion. 32% chose not to disclose their company size. All company sizes were reported in US dollar equivalent.

The responding companies were a good representation of the manufacturing industries, including High-tech and Electronics (25%), Automotive (20%), Life Sciences (20%), Aerospace and Defense (19%), Machinery and Industrial (19%), Consumer Products (11%), and others including federal government. Note that these numbers add up to greater than 100% because some companies indicated that they are active in more than one industry.

The respondents reported doing business globally, with most companies doing business in the North America (65%), about one-half doing business in Western Europe (52%), about one-third doing business in the Asia-Pacific regions (32%), Eastern Europe (14%), and Latin America (8%).

Respondents included manufacturers as well as service providers and software companies, but responses from those determined not to be directly involved in designing software-intensive products (including software vendors and consultants) were not included in the analysis. The majority of companies were considered to have direct involvement in designing and developing software-intensive products and the report reflects their experience.