Study Results for Overcoming Barriers to Implementing and Sustaining Product Development Tools

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Introduction

A capstone project was the final requirement to complete our Master of Science degree in Product Development from the Rochester Institute of Technology (RIT). The project was conducted over the fall and spring semesters of the 2018-19 academic calendar by David C. Roberts and Matthew D. Miles, who chose to examine why engineering tools are difficult to implement and sustain at companies that design and manufacture products. The study explored the various tools that have been proposed to eliminate risk in product development and their level of acceptance in industry. After considering which tools have gained acceptance, we investigated the barriers to implementing and sustaining tools that have garnered less acceptance, and the reasons to advocate for the implementation and sustainment of these tools.

This study used a survey and interviews with product development professionals to investigate what barriers need to be overcome when companies introduce new engineering tools to their product development process. Multiple engineering tools were included on the survey and a case study on a Design for Manufacture and Assembly (DFMA®) implementation was highlighted in the review. Looking back months after its completion, this review, presented at Boothroyd Dewhurst's (BDI) 2019 International Forum on DFMA®, will provide a synopsis of what we found and offer insights to forum attendees looking to embark on their own DFMA® implementation.

Background

Dave and I have similar backgrounds and experiences as mechanical engineers. We discussed these similarities as we went through courses together. Again, starting with our mechanical backgrounds, we both graduated from RIT's Mechanical Engineering Technology program, we have both led implementation of new tools at a company, and both teach/train other engineers. For example, Dave teaches college courses on to how to use 3D computer aided design (CAD) software and I have taught workshops on DFMA® use. Regarding new engineering tool implementations at the companies for which we have worked, we have seen successful integration and use of these tools but have also witnessed areas where tool application has fallen short.

Dave and I were partners in the two Engineering of Systems courses in the graduate program where we were exposed to several product development tools that were studied. We also studied the lean product development (LPD) process and methodology, which is based on the concept that we learn integration, innovation, and feasibility during product development to make good products. Like lean for the manufacturing floor, LPD is a way of thinking to understand the purpose of product development, what it

produces, whether the development system is effective and provides value, while eliminating wasteful steps in the process. As we studied these tools, we observed the following lessons.

- These product development tools have been thoroughly proven out, with successful results.
- The tools should be applied early in the product development process.
- When not used at all, or not used correctly, product results may be subpar, or development projects will fail altogether.

So, with these concepts in mind and considering our own personal experience in product development, we asked:

- With so many proven product development tools that have been available for many years, why do so many companies that manufacture products seem to struggle with their PDP?
- If the best methods for product development are being taught in academia and are considered standard tools for industry, why do so many companies struggle with the implementation and sustainment of product development tools?

This was part of the motivation behind our research.

There are common issues in product development that companies face as it carries a high level of risk. Issues such as the high costs of development, low market acceptance, delayed time to market, poor manufacturability, poor product quality, and low profitability. Also common at many companies, manufacturing engineering and production are often brought in toward the end of the development cycle or completely left out of the development process altogether. This often results in products coming to market lacking well-defined manufacturing processes, with poor process efficiency and poor process quality.

Several tools were proposed to help mitigate these risks. These included tools such as Design for Manufacture (DFM), Design for Assembly (DFA), Design Failure Mode and Effects Analysis (DFMEA), Process Failure Mode and Effects Analysis (PFMEA), Quality Function Deployment (QFD), and Value Analysis/Value Engineering (VAVE). Each of these tools are intended to address specific areas of risk. However, some of these tools have been more readily accepted in mainstream product development, whereas others have not been implemented or maintained at manufacturing companies.

The promise of product development tools to improve product development effectiveness has long been touted. However, we believed that many product development tools have failed to fully gain a foothold at companies and fully deliver on that promise. We explored whether this perception of failure is accurate in industry and investigated why it occurs. The research report looked at the various product development tools that have been proposed to mitigate risk in the PDP and their level of acceptance in industry. After considering which tools have gained acceptance, we investigated the barriers to implementing and sustaining tools that have garnered less acceptance, and the reasons to advocate for the implementation and sustainment of these tools.

Based on our early discussions, literature review, and consulting with our Faculty and Industry Advisors, we developed the following two hypotheses:

1. Companies that develop and manufacture products already have a conventional set of tools and/or methodologies that are adhered to in product development along with cultural standards that are already established. The established tools and culture make it difficult to adopt, implement, and sustain product development tools that would be considered new to the business.
2. The knowledge base of the product development tools within a company fall into either being not known at all, being taught incorrectly, or not taught in an integrated manner. This leads to an insufficient or constantly changing knowledge base that makes it difficult to adopt, implement, and sustain product development tools.

Literature Review

The intent of the literature review is to investigate what areas on the chosen topic have been previously researched and determine what gaps exist that our research was to cover. To start, we determined what tools we would include in the research. This list developed over time after again consulting with our advisors. There were 26 product development tools studied and they are as follows:

3P, A3 Reporting and Management, Competitive Benchmarking, DFMEA, DFA, Design for Environment (DFE), DFM, Design for Service (DFS), Geometric Dimensioning & Tolerancing (GD&T), LPD, Design for Six Sigma (DFSS), Modeling with 3D CAD, PFMEA, Pugh (Decision) Matrix, QFD, Rapid prototyping and/or 3D Printing, Reliability Demonstration, Reusability Assessment, Robust Designs/Taguchi methods, Set-Based Concurrent Engineering (SBCE), Simulation tools and/or Finite Element Analysis (FEA), Theory of Inventive

Problem Solving (TIPS or TRIZ), Trade-Off Curves, VAVE, Visual Management, and Voice of the Customer (VOC)

A company that is attempting to adopt one of these engineering tools into use is doing so to address an area of need or to improve upon within their PDP. Our literature review found recommendations on what tools to use and even which tools to pair together. For example, some existing research papers recommended combinations such as DFMA® and TRIZ, QFD and FMEA within Systems Engineering, and using QFD and TRIZ together. While these examples demonstrated how the tools can be helpful, we found there were gaps on exactly how to implement tools into companies. Additional gaps to implementation plans were how to integrate tools within a PDP, examples of PDP's themselves, how upper management should be involved with a new tool implementation, how to retain knowledge with new tools, and how to balance time and resources during implementations. These were target areas of what we studied.

Methodology

Early in our research, we decided to conduct a survey of product development professionals in order to determine which tools are commonly accepted by manufacturing companies. We built a survey using the online tool SurveyMonkey and sent requests through LinkedIn for product development professionals to take the survey. Our industry adviser, Chris Tsai of BDI, likewise used his LinkedIn connections to advertise the survey. We ended up with 62 respondents across various industries. One of our survey questions asked for individuals who would be willing to be interviewed. The interview approach was selected as a compliment to the survey and as way of obtaining detailed experiences regarding the barriers to implement and sustain development tools.

The survey we developed is shown in Appendix A. There were 25 total questions. The first part of the survey covered general demographics and information about the type of company where the respondents worked. Questions in part one covered individuals experience in product development, company size in terms of employees and revenue, and the number of years the company has been in business. The second part of the survey asked respondents about their familiarity and knowledge of the list of 26 tools. The survey then asked about experiences implementing and sustaining tools, which were deemed unsustainable, and what the barriers are to implement the tools. Some who took our survey volunteered to be interviewed to discuss these tools in greater detail. There was a total of 9 individual interviews for this study. There was a good representation from those in product development roles as

all common levels of employees were represented. One of the interviews was developed into a case study on a DFMA® implementation. This interview highlighted what the company went through with different leaders and different approaches towards trying to sustain DFMA® use over a 15-year period.

Study Results

Figures 1 through 6 show some of the demographic information for our respondents on the survey. We had a wide range of experience in product development. Most respondents worked for larger companies with over 2000 employees, over $50M in annual sales, and that had been in operation for over 50 years. Also, most of our respondents worked for organizations with over 50 people in their product development groups. Over one third of respondents indicated that their company had launched five or fewer new products in the last five years.

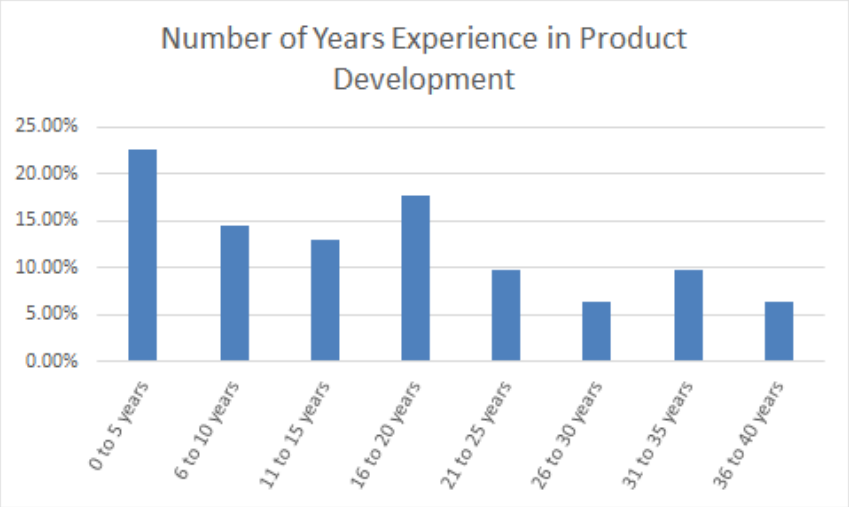

Figure 1 – Results, Survey Question 4: How long have you worked in Product Development?

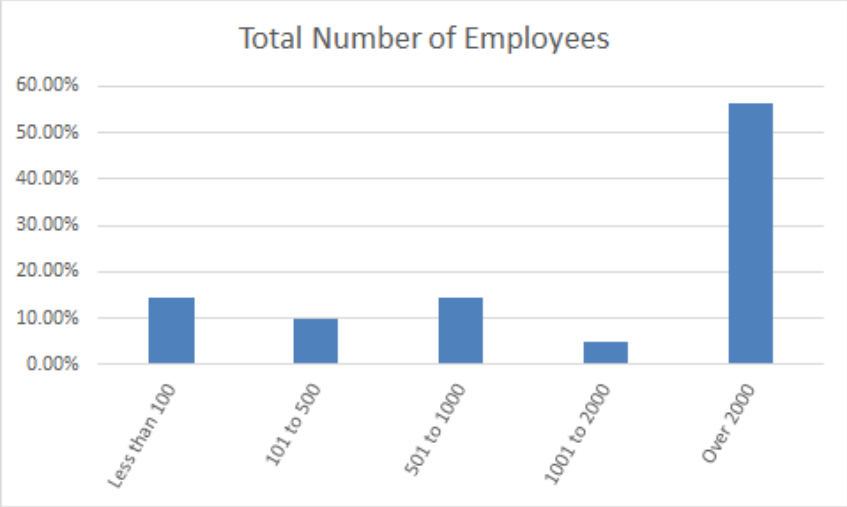

Figure 2 – Results, Survey Question 7: What is the size of your company?

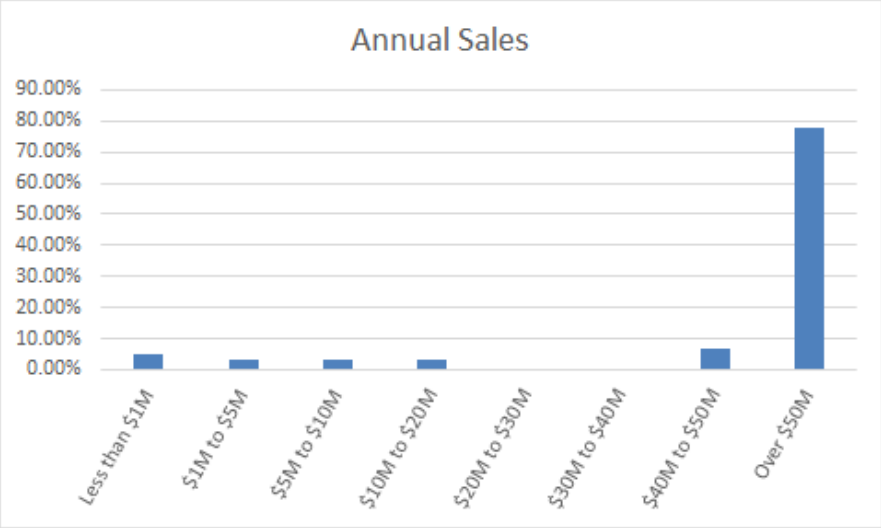

Figure 3 – Results, Survey Question 8: What was your company's annual sales for the last fiscal period?

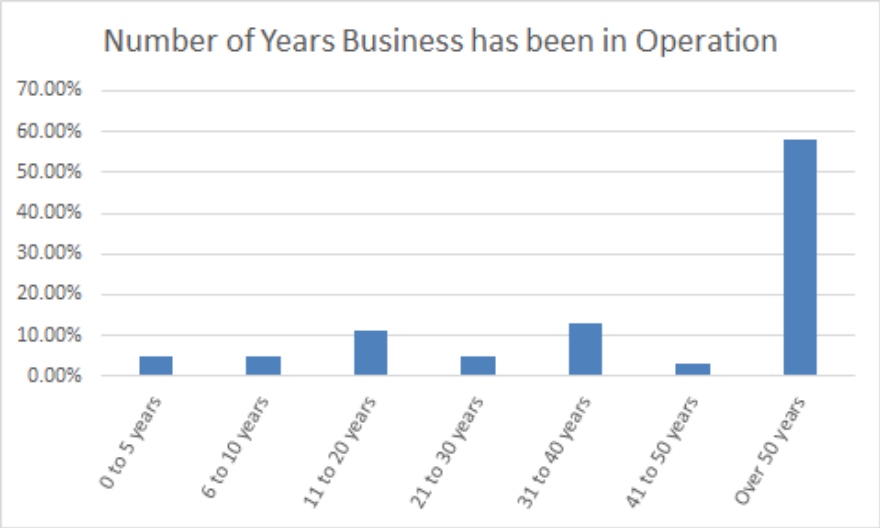

Figure 4 – Results, Survey Question 9: How long has your company been in business?

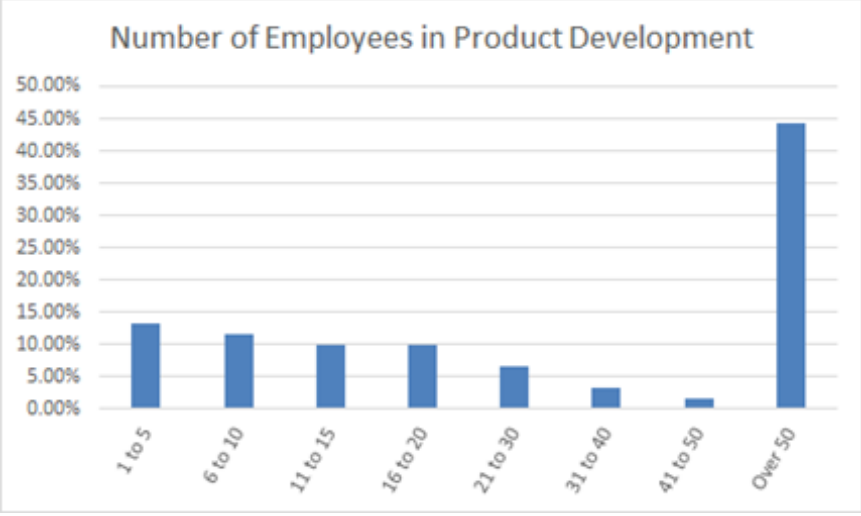

Figure 5 – Results, Survey Question 10: How many employees are generally assigned to your product development department?

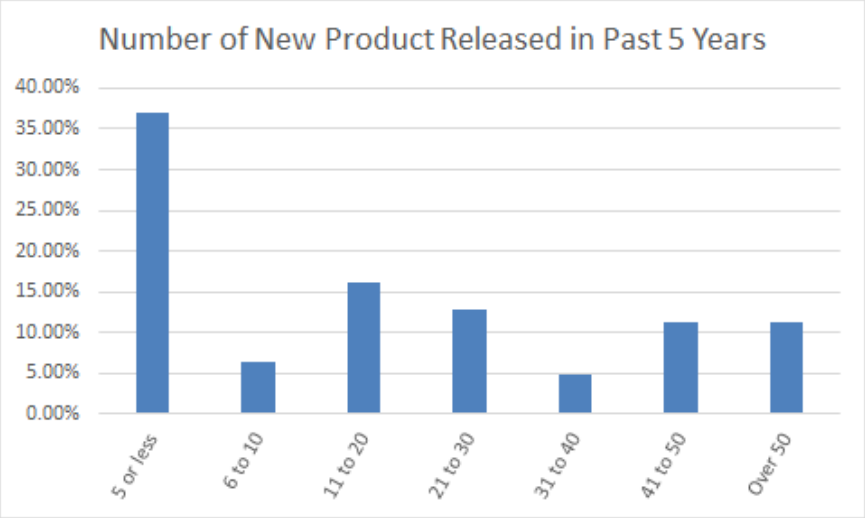

Figure 6 – Results, Survey Question 14: How many new products has your company released over the last five years?

Question 16, we asked respondents to indicate the tools for which they had a high level of expertise and for which they had little-to-no experience (figure 7). 3P was the least well-known tool, with nearly 85% of respondents indicating that they had never heard of the tool. The second least well-known tool was Visual Management, with nearly 66% of respondents indicating that they had never heard of the tool. CAD was the most well-known tool, with nearly 92% of respondents indicating that they had at least moderate expertise with the tool. VOC was nearly as well known, trailing CAD by only about 0.2%. There is some overlap, meaning many respondents indicated knowledge of a development tool, while another large number indicated unfamiliarity with the same tool.

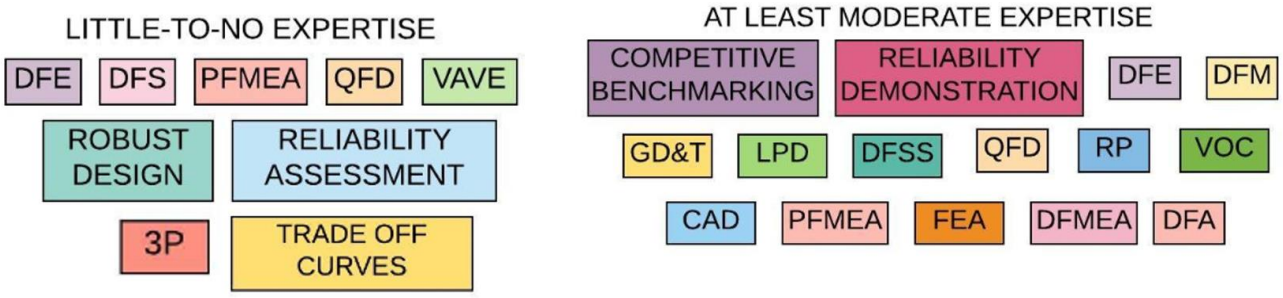

Figure 7 – Results, Survey Question 16: How would you rate your level of expertise with the tool?

Question 17, respondents were asked to rate how frequently they used a tool at their respective development firms, if at all (figure 8). The least used tools included 3P, A3, and TRIZ. The most frequently used tools included CAD, Competitive Benchmarking, and VOC. It is interesting that only about 8 tools are frequently used, whereas on the previous question, there were 15 tools that were well known.

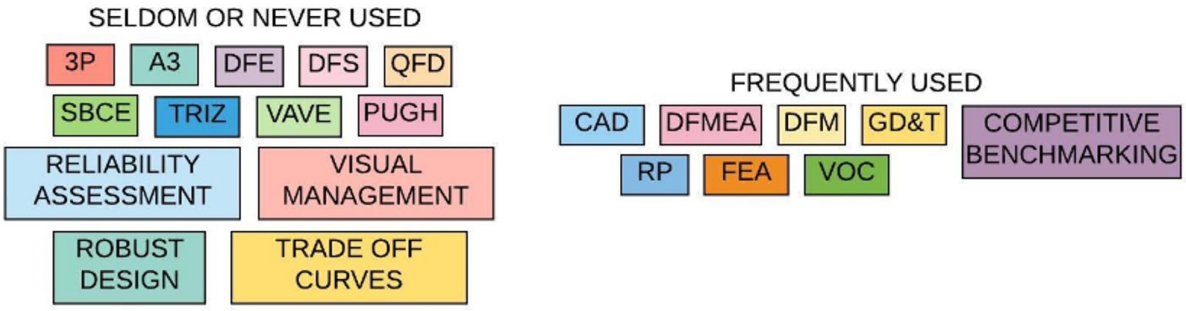

Figure 8 – Results, Survey Question 17: How frequently does your company use the tool in new product development?

Question 18, respondents were asked to rate the level of impact each specific tool was perceived to have on their new PDP (figure 9). Respondents who did not use a specific tool were asked to assess what level of impact they thought would be achievable if such a tool were implemented in their PDP. There appeared to be a correlation between the respondents' level of expertise with the tool and the perceived level of impact that the tool would have on their internal PDP. Respondents that had indicated little-to-no experience using the tool, tended to give it a low rating for level of impact. This indicates that there may be some bias in this regard.

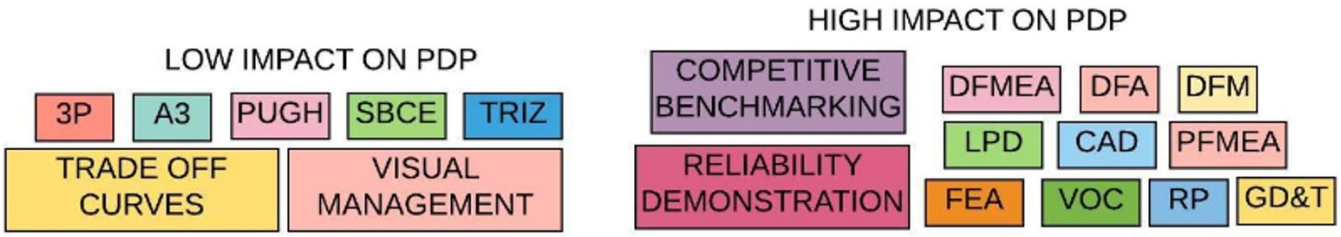

Figure 9 – Results, Survey Question 18: Please rate the level of impact the tool has (or would have, if used) on your company's development of new products?

At this point in the survey, respondents were asked to consider only the NPD tools listed that had been implemented at their respective firms. Question 19, reflecting on the process of implementing these tools, respondents were asked to rate the level of difficulty associated with implementing and sustaining these tools (figure 10). The rating levels were stated as either easy, moderate, or difficult. If the tool had not been implemented, and therefore had no need to be sustained the respondent was asked to check "N/A" for not applicable. Finally, question 20, respondents were asked to specify any development tools that had been implemented, but later deemed unsustainable and therefore discontinued (figure 10).

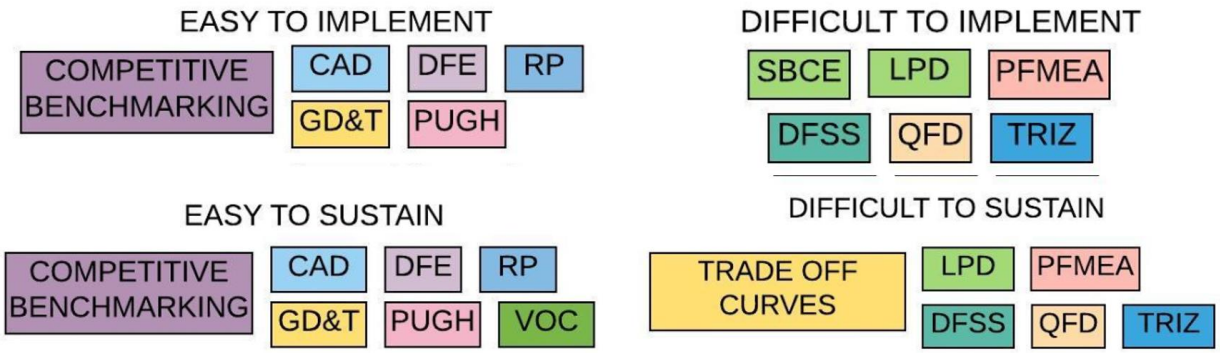

Figure 10 – Results, Survey Questions 19 & 20: For the development tools that are in place at your company, define the ease at which they were implemented? Define the ease to which they have been sustainable or maintain consistent use?

Question 21, we asked respondents to explain why a tool became unsustainable and there appeared to be a lot of commonality between respondents (figure 11). Reasons for tools becoming unsustainable included a lack of support from management, a lack of support from subject matter experts (SME), prohibitive costs associated with implementation or use, time constraints, and a lack of integration of the tool into the PDP. We also asked respondents to provide their thoughts on barriers to adopting new development tools. Barriers included: a lack of understanding regarding the value add associated with the tool, the learning curve, company culture, and geographic location of the business units.

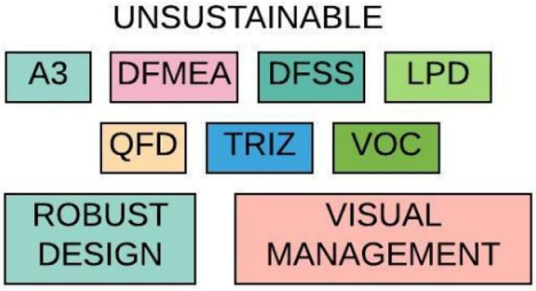

Figure 11 – Results, Survey Question 21: Were there any tools that were implemented, but were challenging to consistently use and found to be unsustainable?

<u>Interviews</u>

Each respondent surveyed and interviewed was assigned a respondent code in order to protect confidentiality. The respondents interviewed, along with their roles in their companies and the industry they serve are also shown in figure 12. We developed a list of common questions we asked each interviewee. In addition to these common questions, we also asked questions specific to their area of expertise and questions related to the information they provided on the survey.

Survey Respondent / Interviewee Code	Current Role	Industry
1029-A	Global DFMA Leader	Consumer Products
1018-C	Product Engineer	General/Multiple Industries
1012-A	Design Engineering Manager	Automotive
1037-A	Vice President of Engineering	General/Multiple Industries
1045-B	Engineering Program Manager	Electromechanical Industrial
1013-C	Senior Director of Supply Chain and Operations	Electromechanical Industrial
1047-A	Vice President of Engineering and Operations	Electromechanical Industrial
1048-A	Engineering Consultant	General/Multiple Industries
1049-A	Director of Corporate Improvement	Electromechanical Industrial

Figure 12 – List of interviewees post-survey.

DFMA® Case Study

A company was studied where they had effectively implemented and sustained Value Engineering and DFMA® tools over the last fifteen years. The company designs and manufactures industrial products. The focus of the study primarily considered the DFMA® tools which were first introduced in 2003. The effort was led by a subject matter expert herein identified as SME-1 who was a middle manager with the organization. Respondent 1049-A (figure 12), the individual who provided the insights into this process, is the current Director of Corporate Improvement and had worked closely with SME-1 during the implementation process.

The respondent noted that Lean was first introduced to the company in the 1990's, with strong support from upper management, specifically referencing the support of the VP of Manufacturing. By 2003, there were five business teams and SME-1 was the engineering manager of one of those teams. The initiative to implement DFMA® tools was driven by aggressive goals for "part count reduction, assembly time, and so forth." It was noted that SME-1 was the key proponent for implementing DFMA®. Furthermore, SME-1 had strong support from upper management to move forward with implementing this tool, having been empowered with "complete responsibility for that product line from a design standpoint."

For 10 years, SME-1 was able to drive support for the DFMA® tools used in the organization. Then in 2013, as is often the case with successful SMEs, SME-1 was promoted to a different role within the company. At this time Respondent 1049-A indirectly became the individual responsible for the continued sustainment of the DFMA® program in the organization. Reflecting on the sustainment of DFMA® tools,

Respondent 1049-A noted that there some challenges along the way. In the economic downturn of 2008/2009, "DFMA® staggered a little bit or was stunted, SME-1 did take on a different role and maybe the team was not as focused as much on those types of design practices because of the economic situations that were among us at that time."

Another challenge noted by the respondent was that not all the business teams had fully embraced DFMA®. SME-1 led one specific team and the other teams had at least given lip service to the program, but it was fully integrated into their processes. Thus, in 2014/2015 Respondent 1049-A was looking to reignite the interest and application of DFMA®. Part of the impetus behind this effort was a week-long workshop on Value Engineering and DFMA®, which was concurrent with the early stages of product development for a new product in development. The training included a cross functional team of close to 30 individuals. Design engineers, manufacturing engineers, assemblers, supply chain personnel, and even a couple suppliers were included in the training.

Due to the role of Respondent 1049-A as Director of Corporate Improvement, the realm of influence was greater than that which SME-1 had in the initial 2003 launch of the tool. Respondent 1049-A had responsibility across all business teams and was able to garner strong support from senior leadership. Additional workshops were organized, each one specific to a new product in development. In order to sustain the DFMA® program moving forward, the respondent seeks to develop a couple individuals on each business who can become the SMEs/champions of the DFMA® program for each team.

Some key lessons learned from this case study include:

- It is imperative to have an SME who leads and drives the initiative with a product development tool.
- While SME possesses the knowledge of the tool, it is also important to develop a plan to spread the knowledge throughout the company.
- Management's role in this case study was minimal, but critical. When interest in this program waned after a cycle of economic downturn, a leader in management was responsible for rekindling the program.
- This case study provided an example of interconnectivity between engineering tools. There was a natural linkage between VE and DFMA®.

- All training conducted occurred with NPD projects in process. Additional tutorials or support training for new engineers focused on application of the tools as well.
- The use of outside consultants in the realm of implementing a tool was also shown to be an effective method to help a program with a new tool.
- There was a noted advantage in having product design and operations collocated.

Conclusions

After conducting all the interviews, we reviewed the recordings and the notes taken. We looked for specific quotes that our Faculty Adviser, Dr. Marcos Esterman (Associate Professor, Rochester Institute of Technology, Industrial and Systems Engineering Department), suggested we identify as "nuggets of information," these being statements that gave specific insight into the reasons for successful or unsuccessful development tool deployment. We identified 128 specific "nuggets" or quotes of interest from the interviews. Using affinity diagramming, these were gathered into 27 specific categories. These categories were then organized into five "super-headers" or key areas that had a critical effect on the success level for implementation and sustainment of product development tools and methodologies. The "super-headers" summary of conclusions are shown in figure 13.

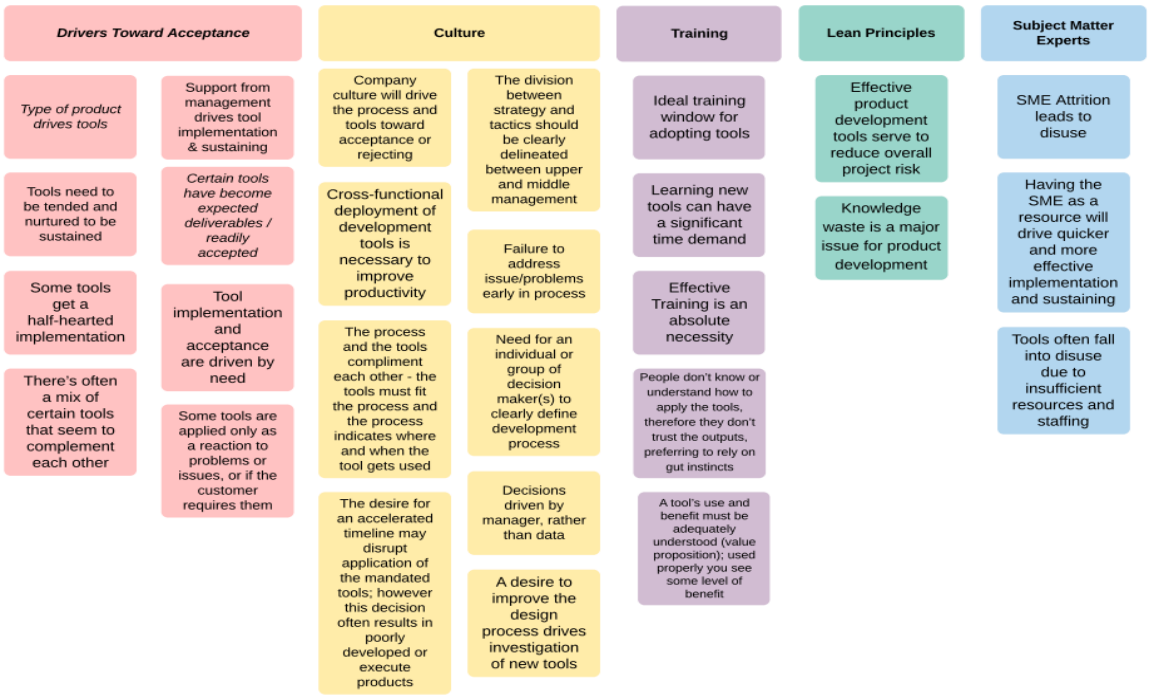

Figure 13 – Affinity Diagram "Super-Headers" based on the interviews.

The first "super-header" in figure 13 can be referred to as "situational" drivers toward acceptance of a new product development tool. These involve factors that exist at a point in time at a company that will accelerate the adoption of specific product development tools. These factors are:

- The product development tool must fit well with the type of product developed by the firm.
- The company's workers must have a specific mindset in order to nurture the implementation of a new development tool. As one respondent noted, the tool must be more than just the "flavor of the month," otherwise its implementation and use will not be taken seriously.
- There is often a mix of certain tools that just seem to complement each other. Therefore, if an organization has already successfully implemented one tool, others may follow more easily. In addition to previous examples of tools linked together, other examples uncovered included CAD with FEA, VOC with both QFD and Pugh Matrix, and VAVE with DFMA®.
- This concept is very important to note: a single NPD tool, by itself, may not provide significant impact to product development efforts. However, a system of NPD tools can have a very significant impact.
- Management support is another factor that will drive acceptance.
- Tool implementation and acceptance are driven by specific needs. Respondents noted that when specific areas of the PDP were identified as needing improvement, tools that had direct application to these areas would be more readily accepted and more likely become institutionalized into the PDP. This was another interesting lesson learned, that of a tool becoming institutionalized into the PDP. This means it becomes a natural part of the process flow, with team members having certain expectations around project deliverables associated with the tool.

The second "super-header" in figure 13 is that the company culture will impact the implementation and sustainment of a new engineering tool. Organizational Culture appears to be a very significant factor that affects product development tool acceptance.

- It was noted that company culture played a significant role in the level of buy-in that could be garnered for an NPD tool.
- The opposing paradigm was the traditional "we've always done it this way" mentality.
- If the desire for continual improvement is lacking and employees feel that the current process outputs are "good enough," the introduction of tools for improvement may encounter apathy or direct resistance.
- A key subset of company culture that was identified was the need for cross functional deployment of a new product development tool. This is contrary to the traditional approach whereby product development is solely the responsibility of engineering. Respondents indicated that successful

tool implementations often involved design engineers, manufacturing engineers, assemblers, members of the supply chain, etc.

- A critical cultural factor related to product development tool implementation and sustainment is the desire and drive to continually improve your process. When a company has successfully created a culture of continuous improvement, individual members of the product development team will be interested in learning new tools and management will support and sponsor this interest.

The third "super-header" in figure 13 is training in the use of a new tool. Training was the next major factor related to our topic.

- This included the concept that there was an ideal training time frame or window related to when the training was received and when it was applied to a project.
- If too much time passed between the training and the application, little working knowledge was retained, resulting in less than satisfactory results.
- One respondent indicated that training workshops for specific development tools were planned at the start of major projects in order to keep the skills fresh and up to date.
- Another key part of training is that it takes time. Time is needed for the user to absorb the information about the tool as well as to practice using it. An organization must be willing to commit the time in order to learn and implement new development tools if they are to be successful.

The fourth "super-header" in figure 13 is the application of lean principles as the next major factor.

- When companies are applying lean principles to their PDP it will drive the adoption of new product development tools.
- Two major tenets associated with lean principles are those of reducing risk and eliminating waste.
- When asked about which tools could implemented to improve their PDP, one respondent replied that introducing FMEA early in the development process could help mitigate the product development risks.
- Several respondents indicated that knowledge waste was a major area of concern.
    - According to author Allen Ward, knowledge waste occurs due to factors such as poor tools, useless information, testing to specifications, and lost/discarded knowledge.

- In order to try to mitigate knowledge waste, some respondents had employed software-based solutions such as Product Life Cycle Management tools or simply home-grown databases.
- One respondent mentioned that their product testing often failed to push the boundaries of performance, thus they tested to standards rather than to failure.
- This led to a gap in their knowledge as to the operating space for their products and may have obscured opportunities for product growth into other applications.

The fifth and final "super-header" in figure 13 is the SME that often leads new engineering tool implementations. SMEs are the champions of knowledge about the development tool being implemented.

- They are the individuals that drive the initiative to implement the tool.
- Often, they are given leadership roles on projects and tool implementation teams.
- A common issue in implementing and sustaining development tools is SME attrition. As several respondents noted, this situation results in lost knowledge. Often, without the SME in place, use of the tool wanes and may eventually fall into complete disuse.

To conclude the results and analysis section, figure 14 illustrates how the sources in the study reinforced the super-header topics developed during the analysis.

Reinforcement Intersections	Survey	Interviews	Engineering Consultant	Project Case Study
Drivers Toward Acceptance	✓	✓	✓	✓
Culture	✓	✓	✓	✓
Training	✓	✓	✓	✓
Lean Principles		✓		✓
Subject Matter Experts	✓	✓		✓

Figure 14 – Reinforcement intersections of sources of study and super-headers.

Recommendations

At the conclusion of this study, the authors reviewed the findings from the survey and interviews to determine what they can take back to their respective companies to apply. To start, any tools currently used should be reviewed to understand how they are sustained and find any areas for improvement. This includes areas previously reviewed, management's involvement, SMEs, proper tool selection for the company, culture change, and knowledge retention. Secondly, if the opportunity arises to introduce a new development tool, there are requirements for a complete understanding of the tool's need and its value, followed by a thorough implementation plan. These early steps to product development tool implementations are perhaps the most significant takeaway from this study for any product development company. This study can provide an outline for the steps to take and factors to consider for new tool adoption.

The start of the initiative would be to understand what tool may be needed, while simultaneously understanding the value it would bring to the business. A structured implementation plan for the tool is recommended. Based on the discussions reviewed in this study, an implementation plan should be considered a "must have" for any business. The appropriate tool must be selected in order to improve the targeted area of NPD. For example, DFMA® might be selected as a tool to start using if a company wants to focus on simplifying their products and improve design for manufacture costs. It is also clear that the plan must factor in the roles of management, an SME, and training.

Within the implementation plan, it must address management's role and support of the adoption of a new tool. This would be management's expectation of deliverables while applied to an NPD project. The appropriate number of SMEs should also be selected to drive the knowledge and training of the tool to other individuals or groups in the business. The SME becomes the leader of the initiative and is involved in the training plan. The training should be developed for and tied to actual company projects with cross functional teams. Often, example products are used to train on for learning a tool. While this helps with learning the basics of an engineering tools, a disconnect can occur between the engineer using the tool and how they apply the tool to their own products if training is not connected to them. Therefore, just as it was discussed in the DFMA® Project Case Study, the recommended advice from Respondent 1049-A was; "If someone asked for advice, I would probably say any training or learning should be connected to a development project or product. In my experience, if I go to a training class, if I don't apply that to something related to my job then I don't retain it very well and I probably don't use it effectively."

Once the initial structure of the product development tool implementation plan is set up, the next steps of the plan is to understand the time required for adoption. Time will be needed in the following areas:

- Time to learning and adopt the tool
- Time to properly integrate the tool into NPD processes
- Time to establish deliverables on projects and expected results
- Time required for culture change within the business
- Time required to retain knowledge

Final recommendations would be to establish how knowledge would be retained. This might include a repository of information readily available to those within the company. Additionally, succession planning of SMEs is recommended to create continuity with tool implementation and adoption. No matter the circumstances of an SMEs departure, companies will want to mitigate any voids created by them.

Shown below (figure 15) is an outline for a recommended product development implementation plan for any company to follow should they choose to start an implementation of any tool.

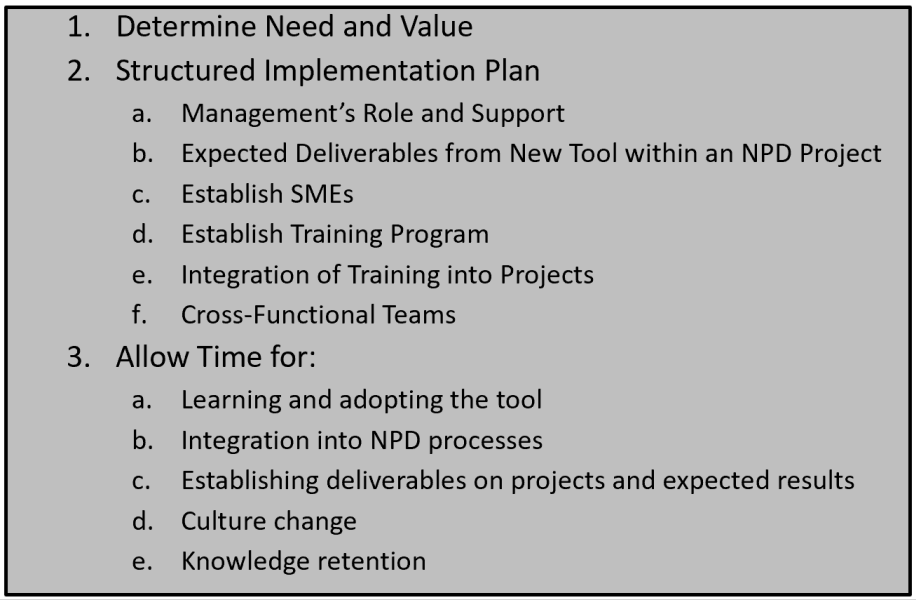

Figure 15 – Reinforcement intersections of sources of study and super-headers.

References

1. Roberts, David C., and Miles, Matthew D. *Overcoming Barriers to Implementing and Sustaining Product Development Tools*. Capstone Project, May 2019.

2. Ward, Allen C., and Durward K. Sobek, II. Lean Product and Process Development. 2nd ed. Cambridge: Lean Enterprise Institute, 2014. Print.

3. Esterman, Dr. Marcos, Associate Professor, Rochester Institute of Technology, Industrial and Systems Engineering Department, *ISEE-771 & 772, Engineering of Systems I & II*, 2016.

4. Personal discussions with Dr. Marcos Esterman of Rochester Institute of Technology, Aug 2016 – April 2017, and Aug 2018 – May 2019.

5. Personal discussions with Roberts, David C., P.E., Senior R&D Engineer, Adjunct Instructor for Science & Technology, Monroe PE Society Board of Directors, Aug 2016 – May 2019.

6. Personal discussions with Chris Tsai of Boothroyd Dewhurst, Inc., Aug 2018 – May 2019.

Appendix A – Survey Questions

Part 1: General Demographics

Instructions/Notes for respondent: The purpose of this survey is to gather information about the tools currently being utilized in the product development process and to consider potential barriers to the implementation of certain tools.

All information about your name and your company name will be kept strictly confidential. Each company and respondent will be assigned a generic code for the purposes of sharing the overall results of the survey without compromising confidentiality.

Please answer the questions to the best of your ability. If there is a question for which you simply do not have enough information to answer, please feel free to skip it.

Q1: What is your name? (note: for internal tracking purposes only; name will be kept confidential)

Q2: What is your company name? (note: for internal tracking purposes only; company name will be kept confidential)

Q3: Do you currently work in product development?

Response choices:

- Yes
- No

Q4: How long have you worked in Product Development? (total time throughout career)

Response choices:

- 0 to 5 years
- 6 to 10 years
- 11 to 15 years
- 16 to 20 years
- 21 to 25 years
- 26 to 30 years
- 31 to 35 years
- 36 to 40 years
- Over 40 years

Q5: In what capacity have you worked in product development? (check all that apply)

Response choices:

- Design/Product Engineer
- Manufacturing/Operations
- Project Manager
- Quality Engineer

Engineer
- Marketing Analyst
- Product Manager
- Research & Development
- Other (please specify)

Q6: What is your current position?

Q7: What is the size of your company?

Response choices:

- Less than 100 employees
- 101 to 500 employees
- 501 to 1000 employees
- 1001 to 2000 employees
- Over 2000 employees

Q8: What was your company's annual sales for the last fiscal period?

Response choices:

- Less than $1 Million
- Over $1 Million up to $5 Million
- Over $5 Million up to $10 Million
- Over $10 Million up to $20 Million
- Over $20 Million up to $30 Million
- Over $30 Million up to $40 Million
- Over $40 Million up to $50 Million
- Over $50 Million

Q9: How long has your company been in business?

Response choices:

- Less than 5 years
- Between 5 and 10 years
- Between 11 and 20 years
- Between 21 and 30 years
- Between 31 and 40 years
- Between 41 and 50 years
- Over 50 years

Q10: How many employees are generally assigned to your product development department? (include engineers, technicians, market analysts, etc.)

Response choices:

- 1 to 5
- 21 to 30

- 6 to 10
- 11 to 15
- 16 to 20
- 31 to 40
- 41 to 50
- Over 50

Q11: How many projects are assigned to a product development team member at any given time?

Response choices:

- Only 1 project at a time
- 2 projects
- 3 projects
- 4 projects
- 5 or more projects

Q12: What industry does your company primarily serve?

Response choices:

- Automation & General Manufacturing
- Chemical processing
- Consumer products
- Electromechanical-Industrial Products
- Engineering, Procurement, and Construction Projects
- Food and Beverage
- General Industrial or Multiple Industries
- Marine
- Mining
- Nuclear
- Oil and Gas
- Pharmaceutical
- Power & Energy
- Primary Metals
- Pulp and Paper
- Water and Wastewater
- Other (please specify)

Q13: How many new products did your company release last year? (either completely new products offered or refresh/updated product designs)

Q14: How many new products has your company released over the last five years? (you can approximate if necessary)

Q15: Many companies categorize new products as follows:

- Sustaining - e.g. expansion within an existing product line
- Distinctive - e.g. related to an existing product line, but with distinctive features or capabilities new to that product
- Breakthrough - e.g. wholly new type of product resulting in a new product family or platform

Considering the products released by your firm in the last 5 years, please estimate the percent that fit each category. Note: please input positive integer values only; entries must add up to 100%.

Response Choices:

- ____ % Sustaining
- ____ % Distinctive
- ____ % Breakthrough

Part 2: Product development tools

Instructions/Notes for respondent: The following section will ask about specific tools that are used in product development. If you are not currently working in product development, please consider these tools in regard to your most recent role in product development.

Our working hypothesis is that many of these tools are not well known or well utilized in product development circles. As you respond to this section, if you find that several of these tools are not well known to you, please indicate this, rather than skipping the question. This is, in fact, what we are trying to determine/confirm.

Q16: Of the following list of product development tools, how would you rate your level of expertise with the tool?

Response Choices (respondent to complete following matrix):

Response → Development Tool ↓	**Never heard of this tool**	**Know what tool is, but little experience with it**	**Have a moderate knowledge of this tool**	**I am well-versed with this tool**	**I am an expert in using this tool**
3P					
A3 Reporting and Management					
Competitive Benchmarking					
Design Failure Mode Effect Analysis (DFMEA)					
Design for Assembly (DFA)					
Design for Environment (DFE)					
Design for Manufacture (DFM)					
Design for Service (DFS)					
Geometric Dimensioning & Tolerancing (GD&T)					
Lean Product Development (different from LSS/DFLSS)					

Design for Six Sigma (DFSS)					
Modeling with Computer Aided Design tools (CAD)					
Process Failure Mode Effect Analysis (PFMEA)					
Pugh (Decision) Matrix					
Quality Function Deployment (QFD; aka House of Quality)					
Rapid prototyping and/or 3D Printing					
Reliability Demonstration					
Reusability Assessment					
Robust Designs/Taguchi methods					
Set-Based Concurrent Engineering (SBCE)					
Simulation tools and/or Finite Element Analysis (FEA)					
Theory of Inventive Problem Solving (TIPS or TRIZ)					
Trade-Off Curves					
Value Engineering (VAVE)					
Visual Management					
Voice of the Customer (VOC)					

Q17: Of the following list of product development tools, how frequently does your company use the tool in new product development?

Response Choices (respondent to complete following matrix):

Response → Development Tool ↓	**Never**	**Seldom**	**On Occasion**	**Frequently**	**Always**
3P					
A3 Reporting and Management					
Competitive Benchmarking					
Design Failure Mode Effect Analysis (DFMEA)					
Design for Assembly (DFA)					
Design for Environment (DFE)					
Design for Manufacture (DFM)					
Design for Service (DFS)					
Geometric Dimensioning & Tolerancing (GD&T)					
Lean Product Development (different from LSS/DFLSS)					
Design for Six Sigma (DFSS)					

Modeling with Computer Aided Design tools (CAD)					
Process Failure Mode Effect Analysis (PFMEA)					
Pugh (Decision) Matrix					
Quality Function Deployment (QFD; aka House of Quality)					
Rapid prototyping and/or 3D Printing					
Reliability Demonstration					
Reusability Assessment					
Robust Designs/Taguchi methods					
Set-Based Concurrent Engineering (SBCE)					
Simulation tools and/or Finite Element Analysis (FEA)					
Theory of Inventive Problem Solving (TIPS or TRIZ)					
Trade-Off Curves					
Value Engineering (VAVE)					
Visual Management					
Voice of the Customer (VOC)					

Q18: Of the following tools please rate the level of impact the tool has (or would have, if used) on your company's development of new products.

1 = little-to-no level of impact; 5 = a significantly high level of impact

Response Choices (respondent to complete following matrix):

Response → **Development Tool ↓**	**1**	**2**	**3**	**4**	**5**
3P					
A3 Reporting and Management					
Competitive Benchmarking					
Design Failure Mode Effect Analysis (DFMEA)					
Design for Assembly (DFA)					
Design for Environment (DFE)					
Design for Manufacture (DFM)					
Design for Service (DFS)					
Geometric Dimensioning & Tolerancing (GD&T)					
Lean Product Development (different from LSS/DFLSS)					
Design for Six Sigma (DFSS)					
Modeling with Computer Aided Design tools (CAD)					
Process Failure Mode Effect Analysis (PFMEA)					
Pugh (Decision) Matrix					
Quality Function Deployment (QFD; aka House of Quality)					

Rapid prototyping and/or 3D Printing					
Reliability Demonstration					
Reusability Assessment					
Robust Designs/Taguchi methods					
Set-Based Concurrent Engineering (SBCE)					
Simulation tools and/or Finite Element Analysis (FEA)					
Theory of Inventive Problem Solving (TIPS or TRIZ)					
Trade-Off Curves					
Value Engineering (VAVE)					
Visual Management					
Voice of the Customer (VOC)					

Q19: For the development tools that are in place at your company, define the ease at which they were implemented? Please select "N/A" if the tool is not implemented at your company.

Response Choices (respondent to complete following matrix):

Response → Development Tool ↓	**Easy**	**Moderate**	**Difficult**	**N/A**
3P				
A3 Reporting and Management				
Competitive Benchmarking				
Design Failure Mode Effect Analysis (DFMEA)				
Design for Assembly (DFA)				
Design for Environment (DFE)				
Design for Manufacture (DFM)				
Design for Service (DFS)				
Geometric Dimensioning & Tolerancing (GD&T)				
Lean Product Development (different from LSS/DFLSS)				
Design for Six Sigma (DFSS)				
Modeling with Computer Aided Design tools (CAD)				
Process Failure Mode Effect Analysis (PFMEA)				
Pugh (Decision) Matrix				
Quality Function Deployment (QFD; aka House of Quality)				
Rapid prototyping and/or 3D Printing				
Reliability Demonstration				
Reusability Assessment				
Robust Designs/Taguchi methods				
Set-Based Concurrent Engineering (SBCE)				
Simulation tools and/or Finite Element Analysis (FEA)				
Theory of Inventive Problem Solving (TIPS or				

TRIZ)				
Trade-Off Curves				
Value Engineering (VAVE)				
Visual Management				
Voice of the Customer (VOC)				

Q20: For the development tools that are in place at your company, define the ease to which they have been sustainable or maintain consistent use? Please select "N/A" if the tool is not implemented at your company.

Response Choices (respondent to complete following matrix):

Response → Development Tool ↓	**Easy**	**Moderate**	**Difficult**	**N/A**
3P				
A3 Reporting and Management				
Competitive Benchmarking				
Design Failure Mode Effect Analysis (DFMEA)				
Design for Assembly (DFA)				
Design for Environment (DFE)				
Design for Manufacture (DFM)				
Design for Service (DFS)				
Geometric Dimensioning & Tolerancing (GD&T)				
Lean Product Development (different from LSS/DFLSS)				
Design for Six Sigma (DFSS)				
Modeling with Computer Aided Design tools (CAD)				
Process Failure Mode Effect Analysis (PFMEA)				
Pugh (Decision) Matrix				
Quality Function Deployment (QFD; aka House of Quality)				
Rapid prototyping and/or 3D Printing				
Reliability Demonstration				
Reusability Assessment				
Robust Designs/Taguchi methods				
Set-Based Concurrent Engineering (SBCE)				
Simulation tools and/or Finite Element Analysis (FEA)				
Theory of Inventive Problem Solving (TIPS or TRIZ)				
Trade-Off Curves				
Value Engineering (VAVE)				
Visual Management				
Voice of the Customer (VOC)				

Q21: Were there any tools that were implemented, but were challenging to consistently use and found to be unsustainable? (check all that apply)

Response Choices (respondent to complete following matrix):

Response → Development Tool ↓	Unsustainable?
3P	
A3 Reporting and Management	
Competitive Benchmarking	
Design Failure Mode Effect Analysis (DFMEA)	
Design for Assembly (DFA)	
Design for Environment (DFE)	
Design for Manufacture (DFM)	
Design for Service (DFS)	
Geometric Dimensioning & Tolerancing (GD&T)	
Lean Product Development (different from LSS/DFLSS)	
Design for Six Sigma (DFSS)	
Modeling with Computer Aided Design tools (CAD)	
Process Failure Mode Effect Analysis (PFMEA)	
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Reliability Demonstration	
Reusability Assessment	
Robust Designs/Taguchi methods	
Set-Based Concurrent Engineering (SBCE)	
Simulation tools and/or Finite Element Analysis (FEA)	
Theory of Inventive Problem Solving (TIPS or TRIZ)	
Trade-Off Curves	
Value Engineering (VAVE)	
Visual Management	
Voice of the Customer (VOC)	

Q22: Based on your answer to the previous question, why were these tools not sustainable?

Q23: In your opinion what are the major barriers to adopting new product development tools?

Q24: Are there any product development tools and practices that were not asked about that you feel are very useful and should be more widely adopted?

Q25: Thank you for taking the time to complete our survey. As a follow up to our survey, we will be conducting one-on-one interviews with experts in the field of product development. If you would be interested volunteering to be interviewed, please provide contact information in the space below. Otherwise, this space can be left blank.