Abstract

One of the biggest challenges in a manufacturing company especially with the worldwide time-to-market race is how to establish a solid integration between R&D and Production entities.

This article describes an old integration model and elaborates some of the related problems, then explains some newer models with better integration techniques. In addition, the “Design For Six Sigma” (DFSS) and lean manufacturing techniques are briefly explained as how they can significantly help on better integration and producing better results.

The main goal in this article is to focus on different models for integration of R&D processes with production to increase efficiency.

Questions include: When and how should the R&D process start? When and how should it be completed? What factors govern the completion stages? What the best practices and methods are to make the hand-off from R&D to production as robust and smooth as possible?

The variety of manufacturing environments make it impossible to provide one global solution to satisfy all the possible needs, however to answer some of these questions, brainstorming methods have been used by conducting several interviews and meetings with a number of plant managers and subject matter experts.

Keywords: NPD (New Product Design), R&D (Research and Development, prototyping and designing the conceptual product), Production: (Manufacturing process for making the final goods), DFSS (Design for Six Sigma), ROI (Return on investment), Time-To-Market: (The length of time to make a product from conceptual design to be available to sale)

Business values of R&D

Dynamic global manufacturers are currently faced with numerous different types of data to process such as inventory, logistics, production and scheduling, quality and process management, finance and material tracking, warranty and field services and many others. Hence the need for optimization and customization is growing rapidly as the market place puts enormous pressure on providing higher quality products with minimum cost and the shortest possible time to produce.

To be successful in this global market, manufacturers should invest enough in research and development to design and prototype new products dynamically. This process of course depends on market-share and customer demands. Along with developing new products, the R&D team should simultaneously be able to communicate with “Production” accordingly. This communication is very crucial as the speedy R&D process can be easily undermined by a long production time, therefore to increase efficiency, the results of R&D should be morphed into production in the shortest time possible.

To provide such a robust and flawless transformation, management should provide sophisticated procedures and a precise strategy.

Challenges

In the following examples we assume there is no purchasing lead-time for raw materials.

Let us picture a fictitious product line in a manufacturing company: The Sales and Marketing department analyzes market-share every quarter and forecasts the demand based on customers’
need and new offering feasibility. Based on their results, R&D defines a certain NPD and creates a workable design in a period of 1 month. Production takes the R&D results and produces the new product with the needed quantity in 2 months and the new product is ready for the customers at the beginning of each quarter. Before the next Quarter begins, the marketing people already have done their homework for the new quarter and have new ideas for R&D team to implement for the new version. This cycle continues and demand is enough to continue selling the old version until the new version arrives.

Of course this is not the picture you see in the real world. The main challenges are proper coordination and resources. Defining a product that you intend to be developed and eventually manufactured is difficult. Not always knowing what the goals are, it suffices to say that R&D requires a lot of resources including funding and people as R&D needs knowledgeable personnel. Also required is input from experts in core technologies relevant to the product. Often a product starts with one goal and during the process of R&D, goals and results change slightly due to different research results or market changes. R&D cannot always produce successful results either. Sometimes efforts and estimates do not match. Additionally, too many new versions confuse customers and create hesitation to buy because there is always news of the arrival of a newer version.

**Classic R&D Integration Model**

![Diagram of R&D integration model]

Both modern and classic R&D models start with Marketing and Sales who directly communicate with customers and understand their needs and desires. This interaction significantly changes the whole manufacturing strategy and the way the entire process should perform. The main inputs are “What to Make”, “Time to Make”, “How often or when to start making another change or new product”.

In modern models the R&D team also provides feedback to the marketing group as to what can be made and the marketing people should try to sell the new ideas to customers.

In any shape or form, counterparts can outperform the speedy performance of marketing, if the R&D and the Time to Make takes longer than it was anticipated.
You can see an example in Figure 1, the marketing team (top level management who are participating with overall main strategy) conveys to engineers and supervisors what needs to be made or changed. They underscore that the new product needs to be ready for sale between 19 to 20 months otherwise they may not be successful due to the fact that the competitors may come up with the same product sooner. They recognize what the price of new product should be and based on the price, demand, ROI analysis and existing resources that they have to put in this process, they should complete the whole process in less than 18 months.

Engineers finish the preliminary process such as gathering requirements and provide the needed specifications and process details. Once they are ready to launch the lab-work, they come together with the R&D team to make the prototype for the new product. This process in the example above is intended to take 12 months to complete. In the meantime the R&D group finds some resource related issues and a few shortages in some equipment which will delay the process 2 months longer than the original estimation. Therefore the manufacturer spends 18 months to complete in addition making the executives nervous about this process.

Finally the R&D process is completed. The prototype works very well according to the specifications. Managers and supervisors are excited to start the production of the new product.

Production people are ready to start the test run however they are lacking some of the important procedures. Some of the other documentation for assembly and production are missing. There are also some software applications which need to be deployed to the production line along with the prototype. The prototype itself has deployment issues, and is not supported by some of the equipment in the production line. There are some performance issues with some of the tools; they have not been tested in production environment before. During the testing of some features, they find some quality issues that are not clear how to fix or who is responsible for fixing them. Management had estimated a maximum one month to finish the test run but fixing all these issues takes 6 months of their time including overtime from the R&D team and themselves.

Finally they finish the test run in 7 months and all the documentation and procedures and applications are ready to move to production from the preproduction stage. Since everything is ready real production takes only 2 days and product is ready to be shipped out.

Unfortunately it is too late. Just a few weeks prior to the completion of the product, one of the competitors comes up with almost the same product with an even lower price. Managers cannot afford to reduce the price since they have spent lots of resources for the extra time. The Sales group has lost some of the customers due to the late delivery and customers have lost their interest and faith in the company. Now sales are extremely weak and after a couple of months they probably cannot afford to continue the new line and it becomes a disaster.

Who’s to blame?
The Executive team wants to know what went wrong. Did they not have all the expertise and enough resources in-house for the NPD? Did they not have enough parts and materials? Why did the production crew not finish their preparation and test runs on time? Why did they not manage to fix the problems they encountered promptly during their test run? Engineers blame R&D; R&D blames the production group and so on.

The truth of the matter is that none of these individual groups performed erroneously. All they did within their entity was standard practice and was procedure driven.

As you can see the real problem is that the communication or hand offs between R&D and production team did not occur, as it should have. Managers did not have a robust system with sophisticated bridge between R&D and production in place.

The R&D group was isolated the entire time and they never communicated during their entire design. In this example they had 12 months of no communication and isolation and when R&D finally released the prototype to production group they (production) did not clearly understand how to correctly implement and
test the prototype. They asked the R&D team frequently about the issues but they (R&D) were busy with the next prototype and did not have enough time to support production not to mention that at this point it was not their responsibility anyway.

As you can see, R&D cannot remain isolated from the production team during the entire process of prototyping and design.

**Modern R&D Integration Model**

![Diagram of Modern R&D Integration Model]

Figure 2 shows a modern integration model; in this model marketing and managers communicate as in the classic model. However when it is time for engineers to create specifications and design requirements, the R&D group are also heavily involved to ensure the specs and requirements are feasible based on the available resources. If necessary they can ask for more resources before it is too late. Also, they can inquire and be provided sufficient training and equipment automation that they need in advance.

In addition, when it is time to start the R&D process they are not isolated from the production team as they were in the classic model.
During prototyping and design, they constantly work with production group to ensure that their prototype can be easily used in the production line later on. In addition, all the new support applications, documentation and blueprints are supervised by the production team and the managers according to the company’s standards.

During the design steps, all the necessary support documents that the production crew need later on will be provided with the help of R&D team and can be revised as they progress.

When it is time for the test run, the R&D team is also involved to monitor the process and update their prototype and documents and prepare it for the real production.

As you can see the R&D process takes more time in this model however it is premeditated and planned accordingly in comparison to the previous model, which lacked the anticipated actual process time due to unforeseen incidents.

**Advanced R&D Integration Model**

In the modern model we have recognized that R&D is integrated heavily with pre-production and test-runs so when test runs are completed, the prototype is ready for production.

In the advanced model, not only is R&D involved with these two departments but also is heavily integrated with all the other departments from the beginning to the end. The product can be shipped to customers from R&D itself and the switching between the R&D line and production line is not happening as you have witnessed in the previous models.

Figure 3 compares these three models. In the classic model each department is isolated and there are non-value added tasks in pre-production and testing, the overall performance, which is the slope of each department’s curve, is compared with the other two and has the average lowest efficiency.

In the second model, stage 1, described in the previous section, has a better efficiency in the first two sections since they are heavily integrated. Also better performance can be seen in testing and overall better results.

In stage 2, which is the advanced model, R&D is involved with all the departments and integrated with all the processes from the beginning to the end. Therefore the overall performance is better than the two other models.

In the advanced model let’s assume that in the beginning, the R&D team starts 100 units to produce and 95 units get scrapped at the early stages and just 5% get shipped out of the factory. This number increases over time as R&D morphs into production as it progresses. When all the 100 units get shipped out successfully, the R&D of that product has been completed and production takes over for producing that product for that model. The R&D crew can now use their full resources on their next NPD. As you can see in this model, R&D is heavily integrated in manufacturing processes and the handoff to production is very smooth.
Figure 3 – Comparing three models

**Design For Six Sigma (DFSS) Approach**

The alternative approach to the classic “Build-Test-Fix” methodology for product development is “Design For Six Sigma” (DFSS) which is a proactive approach for identifying requirements systematically. It uses predictive engineering to ensure that requirements get correctly implemented efficiently and appropriately.

The common method of “Build-Test-Fix” has some tribulations such as several iterations of rebuild-retest-repair.

Implementing DFSS is usually harder to justify than conventional Six-Sigma efforts. In Six Sigma for process improvement, there are always before and after facts therefore managers and executives can be easily convinced by comparing the results.

In designing or prototyping of a new product often there are no before facts. Also companies do not have enough resources to launch multiple methods for the same product design to compare the results and choose the best method.

A good example of using DFSS in modern product development is Apple computer’s development of the iPod nano. Most of the companies who have participated in this methodology for launching their new products refuse to share any information globally due to the market competition.

The goal of the lean product development process is to deliver the maximum value in the product by using less resource with the following characteristics:

1-Capturing the voice of customer accurately
2-Using most appropriate technology and design to accomplish the most value and quality in the product
3-Transforming the voice of customer into a high quality design that is low cost, high speed and uses fewer resources

4-Decresing the waste in the product development life cycle

In lean manufacturing the main focus is reducing waste and increasing speed but in lean product development the focus is both on reducing waste, increasing speed and also on increasing the value of the product.

The Lean product development methodology consists of three main management approaches:
1-Lean Task Management
2-Lean knowledge and information management
3-Creating Lean Products

**In lean task management**, the focus is on increasing “value added” tasks, decreasing “non value added but necessary” tasks and significantly reducing “wastes”. Also the goal on value added tasks is to reduce the interruptions and increasing efficiency.

**In lean knowledge and information management**, the focus is on producing knowledge and information like a “super market”. It should be fresh and not outdated, easy and fast to access, systematic and organized so one product should not be completely different with another one when it comes to information organization. The information should not be redundant and hard to access. The data and information should be generated in all levels from the beginning of design process and should be ready for integration into production properly with predictive methods.

**In lean product design**, the focus is to reduce unnecessary functions and parts, loosen up unreasonable or redundant tolerances, using standard parts, outsourcing if it makes more sense, control the technology behind the design to be standard and inclined with companies’ strategy so it can be easily supported and integrated into the production floor, avoid complicated user or operator’s requirement, and avoid complicated interface requirements.

Similar to the “Define, Measure, Analyze, Improve and Control” (DMAIC) phases in the Six Sigma approach, DFSS consists of ICOV steps:

1. Identify Requirements (I): Draft the project charter and identify customer and business requirements.
2. Characterize the design (C): Transfer customer requirements to technical functional requirements. Also generate design alternatives. Evaluate the alternatives.
3. Optimize the design (O): optimizing the main design by using computer simulation and modeling techniques.
4. Validate the design (V): testing, using DFMEA (design failure mode –effect analysis) and verification and piloting.

A Six Sigma –capable company is a company in which each of the services and products achieves 3.4 defects per million in long-term capabilities. A DFSS – capable company is a company which has less than 3.4 non-conforming decisions per million decisions.

**Conclusion**

The main goal in a manufacturing company is to make the desirable product, which the customers want immediately, with the expected quality by customers, and with the lowest feasible price.

R&D cannot remain isolated from the production team during the entire process of prototyping and design. The integration between R&D and production is critical and convoluted. Integration of R&D with production transpires not just while finishing the design process but it is fully involved from the beginning to the end. The predictive engineering methodology should be used to determine what tools, resources and services would be needed to have a successful on-time production with no interruption.
The whole manufacturing process consists of three major sub-processes: design and prototyping, production and offering services after sales. For all these processes a robust and successful manufacturing company should measure the performances and constantly seek improvement to reduce waste and increase efficiency.

The Implementation of DFSS in the design stage, using standard tools and standard information, increasing performance while decreasing the number of non-conforming decisions over the long terms is essential for a robust and successful manufacturing business.

**Valuable Quotes**

Les MCphee \(^1\) says: "The best practices and conclusion will be different depending on how much true research and how much development or design is required. In general terms, activity begins with a recognized need. Usually this means a customer requirement.

The best vision for the whole system is not to be visualizing the processes as being serial. Time to market is critical in most development projects and success is only achieved quickly if the requirements, design, production and sales are iterative and simultaneous also they are in sync and integrated. Many companies find success in releasing basic model products to meet early delivery and then adding features and upgrades to feed further sales. There are some risks to this strategy however. If the product changes too fast customers may wait to buy.

Customers, engineering, production and quality need to work together. The concept of handoffs doesn't usually work well. Over the lifecycle of a product all parties maintain a role. The lead role will change but everyone is still active. **R&D is never truly completed until the product has been retired.**

The great challenge for many companies is what is referred as “handoff to manufacturing”. The manufacturing people need to be involved from the beginning of the design to ensure that the production capability is ready when the design is. The design must also meet basic requirements for manufacturability or the product cost will be higher."

*Christian Yorgure* \(^2\): “R&D team’s result is as good as its leader’s record keeping ability/interest. The team should include all relevant departments early enough. Assign roles, document all you can, do not be swift to throw out any data. Remember that your documentation is your only ingredient for both prototyping and eventual manufacture."

Jeffrey Antman, PE \(^3\) says” Have the right team. Accept that any problem you see in development will be a bigger problem in production. Assemble a team where a core group will stay with the product from development through production. Your team will approach development problems like they will have to live with them through production and not toss them over the fence to some unsuspecting manufacturing type while they move on to the next new project.”

**References:**

3- Jeffrey Antman, 2009, PE - Great Basin Scientific - Greater Denver Area Industry Medical Devices
4- “Kai Yang”, 2009. Design For Six Sigma; A road map to product development; MC Graw Hill; USA.