ADVANCED MANUFACTURING PROCESS- RAPID PROTOTYPING

INTRODUCTION:

Among all the available prototyping techniques, rapid prototyp ing takes minimum time to fabricate physical model from 3D CAD data [1,2]. RP process was originally started to make prototypes, which were deemed very costly for the final products [3]. However, recently with the introduction of numerous inexpensive desktop printers, it is used for the low volume production [4,5]. Each technology is working on different principal of operation. Rapid Prototyping Technology has a limitation that most of the available materials are not suitable for RP technology [6,7]. This can be overcome by evolution of new materials in future [8,9].

Rapid prototyping is the fast fabrication of a physical part, model or assembly using 3D computer aided design (CAD). It is an agile strategy used throughout the product development process. With this approach, 3-dimensional prototypes of a product or feature are created and tested to optimize characteristics like shape, size, and overall usability.

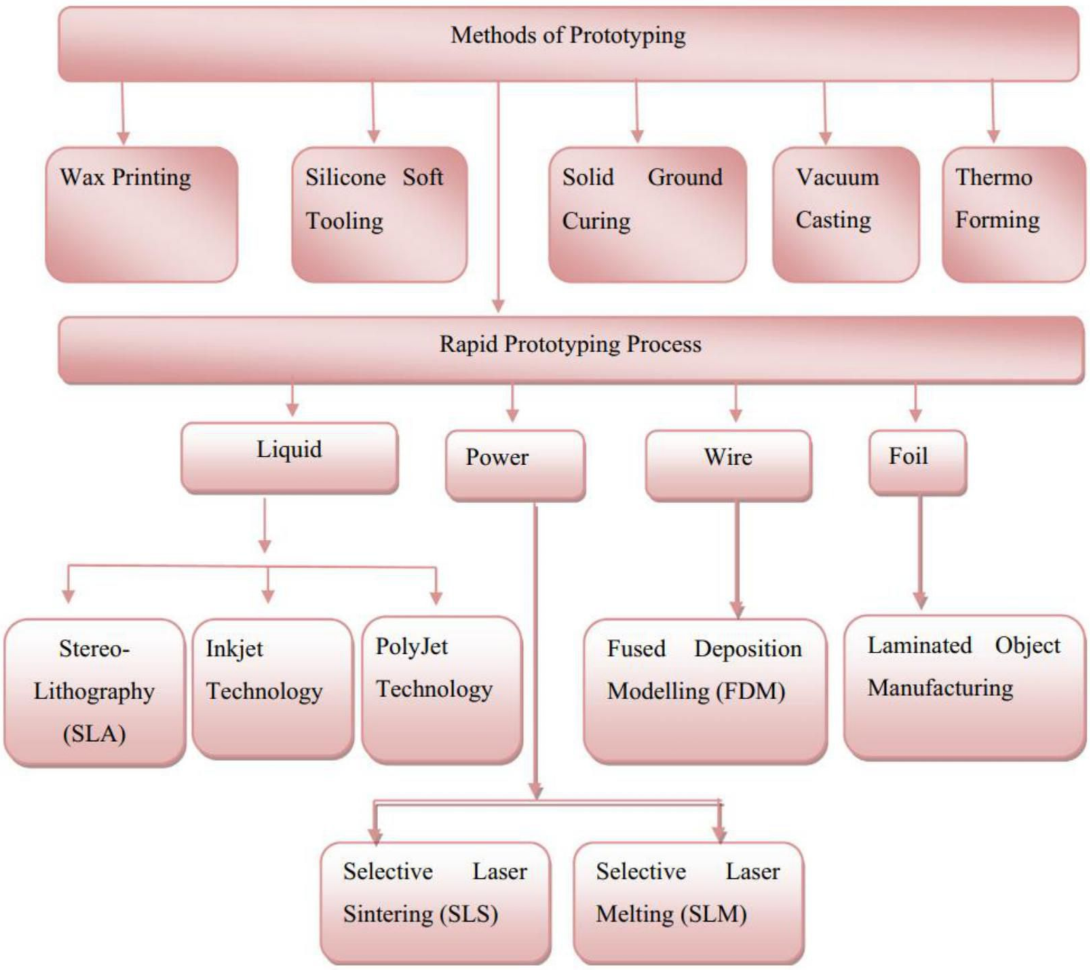

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Figure 1: Classification of Rapid prototyping methods[10]

Rapid prototyping creates product simulations for testing and validation during the product development process, with multiple iterations generated during a short period based on user feedback and analysis. Where the design closely matches the proposed finished product, it is said to be a **High-Fidelity Prototype**, as opposed to a low fidelity prototype, where there is a marked difference between the prototype and the final product.

HOW DOES RAPID PROTOTYPING WORK?

Rapid prototyping (RP) includes a variety of manufacturing technologies, although most utilise layered additive manufacturing. However, other technologies used for RP include high-speed machining, casting, moulding and extruding.

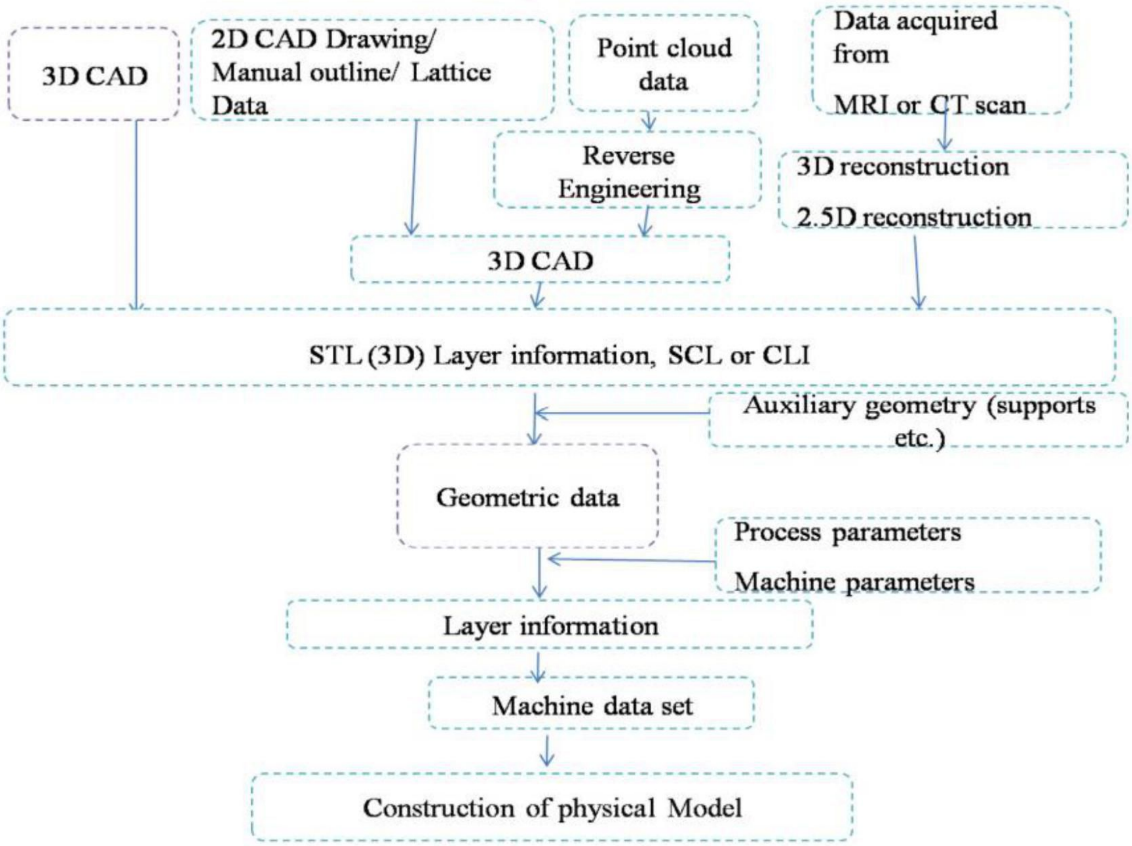

Figure 2; Data flow in Rapid Prototyping.

While additive manufacturing is the most common rapid prototyping process, other more conventional processes can also be used to create prototypes.

These processes include:

- **Subtractive** - whereby a block of material is carved to produce the desired shape using milling, grinding or turning.
- **Compressive** - whereby a semi-solid or liquid material is forced into the desired shape before being solidified, such as with casting, compressive sintering or moulding.

WHAT ARE THE DIFFERENT TYPES OF RAPID PROTOTYPING?

❖ **Stereolithography (SLA) or Vat Photopolymerization**

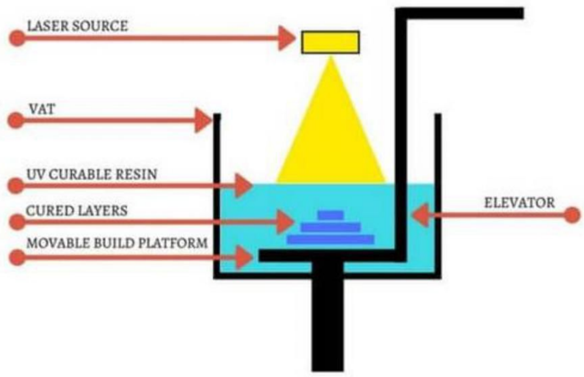

Figure 3: Stereolithography

This fast and affordable technique was the first successful method of commercial 3D printing. It uses a bath of photosensitive liquid which is solidified layer-by-layer using a computer-controlled ultra violet (UV) light. In this process, a perforated platform is used just below the surface of a vat of liquid photo curable polymer [11]. In SLA process, UV laser beams are used to trace the first slice of the component to be fabricated and hardened thin layer of photopolymer material.

Applications:

- *Fit/form, proof of concept prototypes and engineering verifications*
- *Investment Casting Patterns Rapid Tooling,*
- *Jigs & Fixtures*
- *Designer models, snap-fit assemblies*
- *Scale & exhibition models*
- *Optics, transparent covers*
- *Molds & casting patterns*

❖ **Selective Laser Sintering (SLS)**

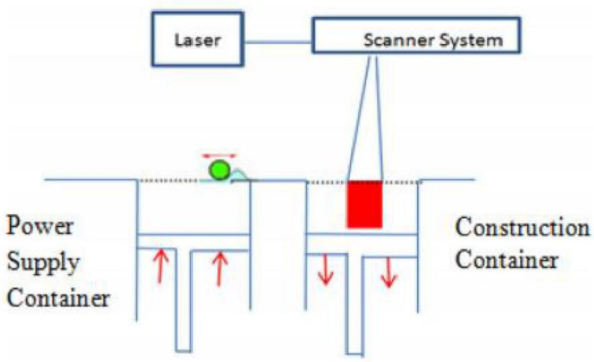

Figure 4: Selective Laser Sintering

Used for both metal and plastic prototyping, SLS uses a powder bed to build a prototype one layer at a time using a laser to heat and sinter the powdered material. However, the strength of the parts is not as good as with SLA, while the surface of the finished product is usually rough and may require secondary work to finish it. . In SLS process, a roller is used to spread the power of build material over the surface of build cylinder. Piston in the cylinder moves down one layer thickness to form a new layer of powder. In material supply cylinder, piston moves in upward direction of one layer height to supply the measured quantity of powder for each layer. A laser beam is used to trace the surface of rigidly compacted powder, which melt and join the grains together to form a solid object. It is required to maintain the temperature of the fabrication chamber below the melting point of the powder.

Applications:

- *Dental implants*
- *Aerospace applications, e.g. Airplane doors bracket*
- *Hydraulic blocks*
- *Close contour complex tempering channels*
- *Automotive industry, e.g. axle*

❖ **<u>Fused Deposition Modelling (FDM) or Material Jetting</u>**

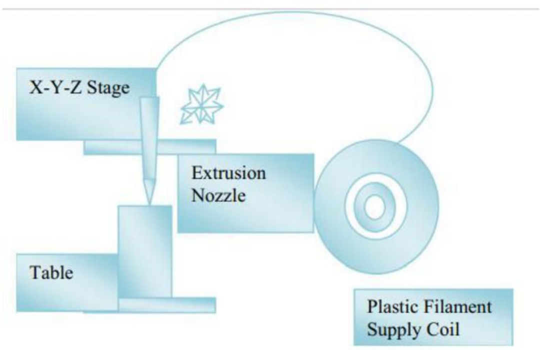

Figure 5: Fused Deposition Modelling

This inexpensive, easy-to-use process can be found in most non-industrial desktop 3D printers. It uses a spool of thermoplastic filament which is melted inside a printing nozzle barrel before the resulting liquid plastic is laid down layer-by-layer according to a computer deposition program. While the early results generally had poor resolution and were weak, this process is improving rapidly and is fast and cheap, making it ideal for product development. . In FDM process, a plastic filament is supply to the extrusion nozzle and nozzle is heated to melt the material. There are mechanisms, which allow the flow of the melted material to be turned on and off. X-Y plotter type mechanism is used to trace the geometry as per the sliced CAD data. There is a provision of another nozzle, which is used to supply the support material. The entire system is attached within a close chamber and maintains a constant chamber temperature below the melting point of the material.

Applications:

- *Printed prosthetics*
- *Aerospace industry*
- *Medical Industry*
- *Arts sector*

❖ <u>Selective Laser Melting (SLM) or Powder Bed Fusion</u>

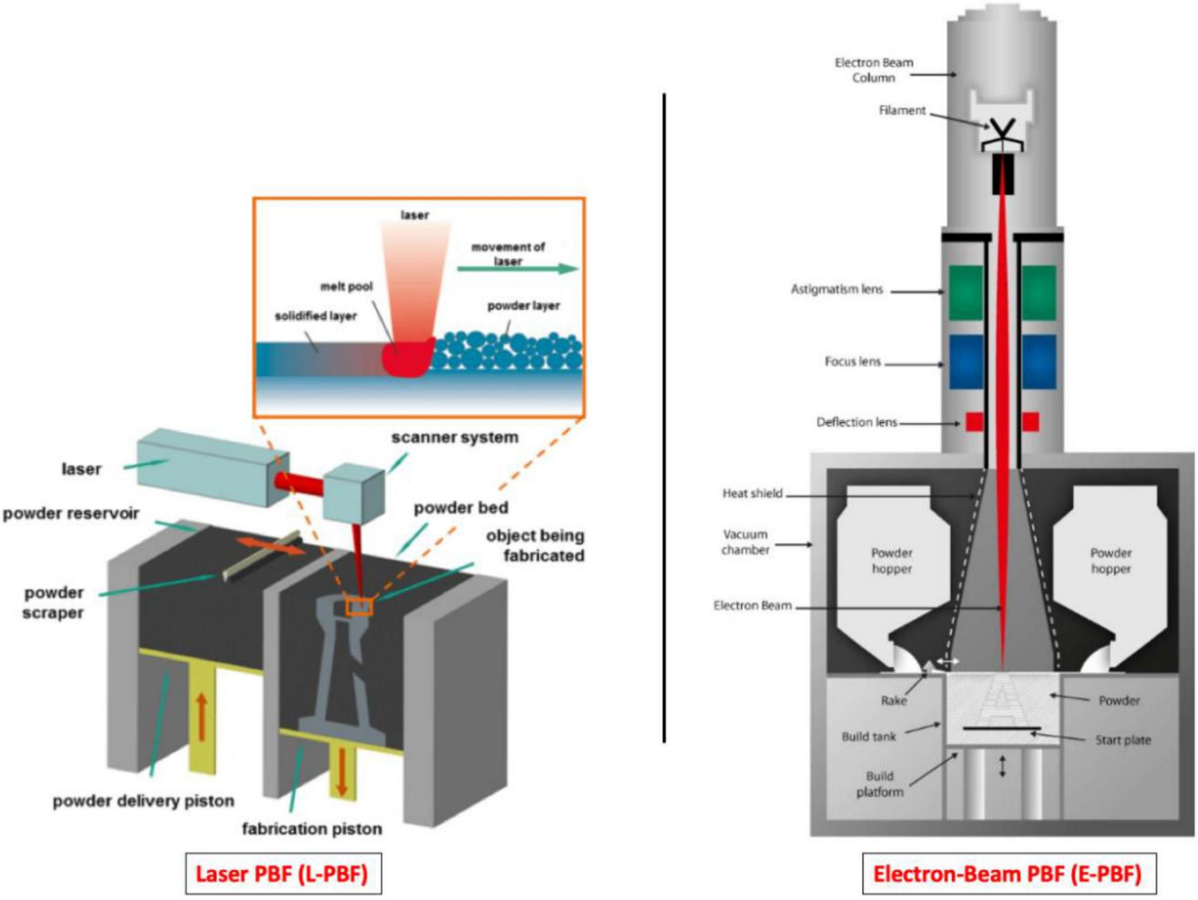

Figure 6: Selective Laser Melting

Often known as powder bed fusion, this process is favoured for making high-strength, complex parts. <u>Selective Laser Melting</u> is frequently used by the aerospace, automotive, defence and medical industries. This powder bed based fusion process uses a fine metal powder which is melted in a layer by layer manner to build either prototype or production parts using a high-powered laser or <u>electron beam</u>. Common SLM materials used in RP include titanium, aluminium, stainless steel and cobalt chrome alloys.

Applications:

- *Fixed dental prostheses*
- *Functional parts that need to resist to high pressure and heat.*
- *Industrial tooling and other production tools.*

❖ Laminated Object Manufacturing (LOM) or Sheet Lamination

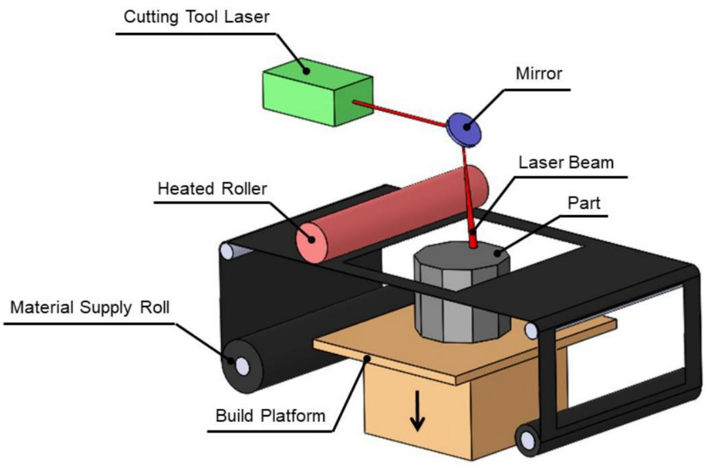

Figure 7: Laminated Object Manufacturing

This inexpensive process is less sophisticated than SLM or SLS, but it does not require specially controlled conditions. LOM builds up a series of thin laminates that have been accurately cut with laser beams or another cutting device to create the CAD pattern design. Each layer is delivered and bonded on top of the previous one until the part is complete.

Applications

- *mainly used for rapid prototyping plastic parts.*
- *can't create really accurate models such as technologies like Selective Laser Sintering (SLS), or even Stereolithography (SLA). It is not possible to print intricate and complex geometries, but its cheap process and freeform fabrication process are making it a good prototyping technique.*

❖ Digital Light Processing (DLP)

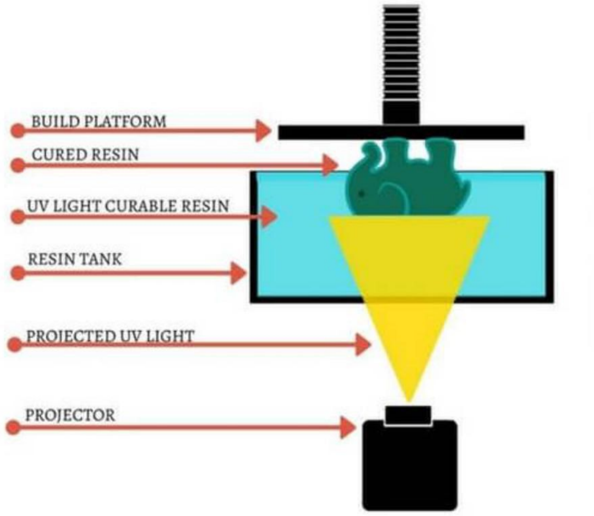

Figure 8: Digital Light Processing

Similar to SLA, this technique also uses the polymerisation of resins which are cured using a more conventional light source than with SLA. While faster and cheaper than SLA, DLP often requires the use of support structures and post-build curing.

An alternative version of this is Continuous Liquid Interface Production (CLIP), whereby the part is continuously pulled from a vat, without the use of layers. As the part is pulled from the vat it crosses a light barrier that alters its configuration to create the desired cross-sectional pattern on the plastic.

Applications

- *Projectors*
- *High-quality, seamless, all-digital images that have exceptional stability as well as freedom from both flicker and image lag.*
- *DLP-based mobile projectors*
- *Digital photofinishing for high process speed minilab and maxilab applications*
- *DLP Cinema for the digital delivery of films to audiences around the world.*

❖ **Binder Jetting or Versatile 3D printing technology**

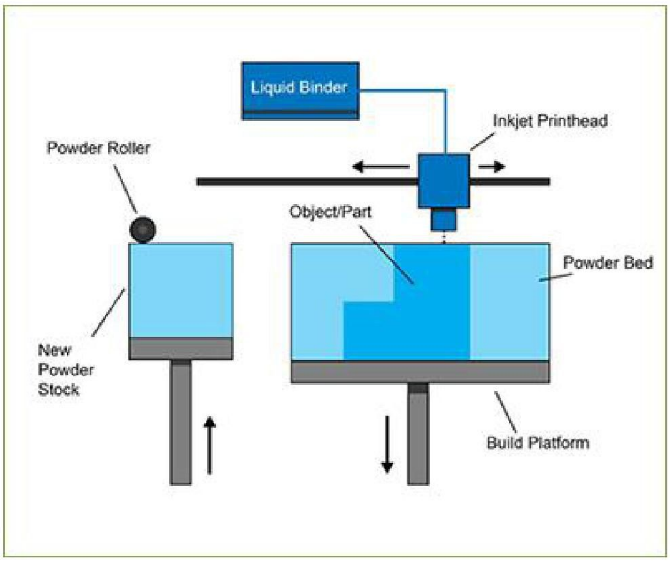

Figure 9: Binder Jetting

This technique allows for one or many parts to be printed at one time, although the parts produced are not as strong as those created using SLS. Binder Jetting uses a powder bed onto which nozzles spray micro-fine droplets of a liquid to bond the powder particles together to form a layer of the part.

Each layer may then compacted by a roller before the next layer of powder is laid down and the process begins again. When complete the part may be cured in an oven to burn off the binding agent and fuse the powder into a coherent part.

Applications

- *Sand Casting Cores and Molds*

- *Metal Binder Jetting*
- *manufacture very large parts and conplex metal geometries, as it is not limited by any thermal effects (e.g. warping).*

WHAT ARE THE ADVANTAGES OF RAPID PROTOTYPING?

There are a number of rapid prototyping advantages, such as being able to gain a more complete picture of how a product will look or perform in the early stage of the design and manufacturing cycle, allowing changes or improvements to be implemented earlier in the process. The time this takes can vary from a few days to a number of months, depending on the methods used.

Speed
Using rapid prototyping, you can have your part or product designed and tested in a short timeframe. This allows you to have a full-scale model ready to determine whether it meets your requirement or not. If it's all good, then you can approve the full production of the product and move on to develop more products. If there are design flaws, then you can either work on iterations or discard the idea altogether. With rapid prototyping, you did not waste much time as you would in the traditional method.

Cost
It has been said repeatedly, but rapid prototyping is the most cost-effective among the forms of prototyping. This is because you are dealing with low volume production and will not spend as much in the final production model. It allows you to do product testing without great financial risk. This help to keep your production within the budget and will save your money further in case the prototype turned out to be a success.

Full-scale model for approval
Depending on your business model, with rapid prototyping, you can send physical model for the client and management's approval. These prototypes can help them determine its viability, effectiveness, and reception of the market before an order for full-scale manufacturing is made. The feedback from multiple sources can help improve the final design to gain the upper hand in the market.

WHAT ARE THE SHORTCOMINGS?

Insufficient analysis
When the focus is on a limited prototype, it can distract the product developers from doing proper product analysis of the complete project. They may overlook a better solution, or may not complete the specification that will result in poor engineered projects that can be hard to maintain.

User Confusion
If a prototype reached the customers, they might mistake it for the final product. If what they see is a rough prototype, they will not understand that it is subject to further finishing or polishing and may perceive that it is the actual performance or appearance of the final product. Worst, they may grow found a prototype feature that will not be included in the final product.

Limited Options
Rapid prototyping techniques can also limit your option. There are many other options available to make a prototype. Although they are not as fast, they have many good features too like creating many moving parts that interlocks and work together. In complicated projects, rapid prototyping may not be the best choice.

CONCLUSION

Rapid prototyping can be an invaluable time-saver and disaster-avoider for product teams. With dependable feedback from users interacting with prototypes, product managers have qualitative validation of their assumptions or clear indicators that adjustments are required. This all helps reduce the risk of the final product failing to meet expectations.

Additionally, the externalized thinking that comes from the rapid prototyping process breaks down communication barriers and fills in the gaps. This ensures the development organization delivers what the product team envisioned. This also creates more efficiency in the overall product development process and puts the best possible product before paying customers and prospects.

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