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Make or Buy: Case Study of 3D Printing Spare Parts Adoption

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Abstract---*3d printing technology open up possibility of manufacturing industry to make own spare parts for machinery instead procure to vendors. Limitation of 3d printed spare parts mostly on physical characteristics have to get attention and assessment of spare parts that can be printed are presented. In this paper also discussed factor-factor as framework to help make decision on should a company make 3d print parts or buying from vendors. Case study on three companies at textiles, pharmaceuticals and machining sectors found that adoption of 3d print technology to make spare parts for their operation is inevitable as long as low volume and frequency and at cost 40-60% of buying products. Major risk that face using 3d print are reliability and quality products at initial period adoption, and eventualy will decrease as gaining more knowledge on implementation time.*

Keywords---*Printing spare, Adoption.*

I. INTRODUCTION

Wave of industry 4.0 has come to all aspect of manufacturing industry today. Ready or not will define state of industry in the future. Even automation as part of industry 4.0 has known in industry before, but smart industry that using internet as enabler on production system still infant in Indonesia. One of development industry 4.0 is adoption 3d printing technology in Industry for product modeling and design (Anwar, A., 2019). Classification 3d printing technology as additive manufacturing has wide range from photo polymerization, power bed fusion, material extrusion, material jetting, direct energy deposition (ASTM, 2011).

Major impact of 3D printing technology from innovation (Rayna and Struitkova, 2016), supply chain (Mohr and Kahn, 2016) with establishment 3d printing service (Sasson and Johnson, 2016) and intellectual property (Bradshaw, Bowyer and Haufe, 2010). Despite positive or negative impact that 3d printing technology bring to manufacturing industry, these technology wave cannot see as replacement of mass production but as complement to manufacturing industry to create competitive advantage with better speed of innovation and product delivery at low cost.

Problem still inherent to 3d printing are product size limited with machine size, slow production rate and lack of skill on 3d design. The first two aspect make 3d printing as mass production make adoption rate at manufacturing industry in Indonesia slower, because of production cost. Moreover the cheapest 3d printing technology at most manufacturing industry or hobbyst level at home is material extrusion or filament deposition machine that use plastic filament to print product. Appropriation these 3d printing technology at Indonesia manufacturing industry, that viable to print spare parts or components for machinery maintenance. Dependency on spare parts that has to import from other countries still hurdles to improve availability and productivity.

In this paper we discuss on framework to make or buy decision on 3d print component for machine spare parts in maintenance activity that carried in manufacturing industry.

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II. LITERATURE REVIEW

II.I. 3D Printing

3D printing categorized as additive manufacturing and definition by American Society for Testing and Materials (ASTM, 2011) "a process of joining materials to make objects from 3D model data, usually layer upon layer, as opposed to subtractive manufacturing methodologies"

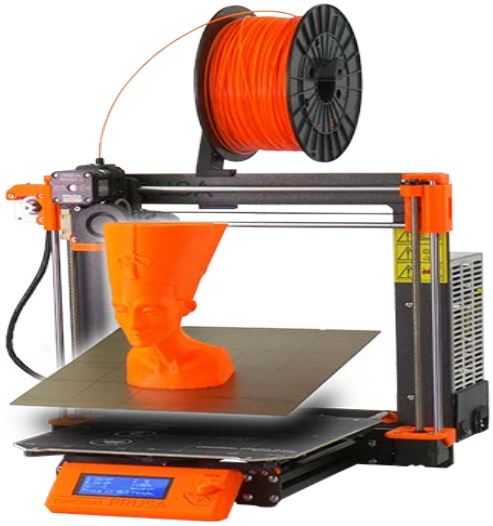

Figure 1: *Consumer Grade Prusa 3D Printer*

3d printing technology start with 1980 with grant patent of stereolithography to Chuck Hull and commercial company Stratasys begin patented Fused Deposition Modeling (FDM) and selling 3d printer. High cost of 3d printer make academic strat to develop their own cost economic 3d printer trough Rep Rap project by Dr. Adrian Bowyler. This movement open the doors for massive development hobbyist level of 3d printer as Do It Yourself to make their own printer until now. Today we can different 3d printing technology, as follow:

- Binder Jetting, a liquid bonding agent is selectively deposited to join powder materials.
- Directed Energy Deposition, thermal energy is used to fuse materials by melting as they are being deposited
- Material Extrusion, material is selectively dispensed through a nozzle or orifice
- Material Jetting, droplets of build material are selectively deposited.
- Powder Bed Fusion, thermal energy selectively fuses regions of a powder bed
- Vat Photopolymerization, liquid photopolymer in a vat is selectively cured by light activated polymerization

Basic workflow to use 3d printing technology involved:

- Designing part or object using 3d CAD, eksport to STL Files
- Generate g-codes based on STL file and printing parameters
- Sent g-code to read and print on 3D printer

II.II. Spare parts and 3d Printing

Maintenance management is a regular and systematic approach to planning, organizing, monitoring and evaluating maintenance activities and costs. A good maintenance management system combined with knowledge and maintenance staff is able to prevent health and safety problems and environmental damage; produce living assets with fewer disruptions and result in lower operating costs and a higher quality of life. A good maintenance management indicate by availability spare parts (inventory) for machine. Research on spare parts inventory has wide range from classical view of most basic inventory management EOQ, ROP, ABC analysis, MRP to sophisticated with probabilistic and joint with reliability, economic and other external factors accounted.

Keeping spare parts for maintenance have other problem inherent with probabilistic event of spare parts replacement. These condition make harder for industry to keep optimal number of spare parts in their inventory and make more appropriation of using 3d printing spare parts to overcome this problem.

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Svensson and Tunborg (2017) posits the classification spare parts suitable for 3d printing :

- Low Volume
- Low Frequency
- Uncertainty of demand
- Value
- High Supply Risk

And limitation to produce spare parts on 3d printing:

- Investment Costs
- Speed
- Material
- Object size
- Part strengths
- Surface finish

II.III. Make or Buy

Make or buy decision show us a basic dilemma facing by manager understanding how allocation in-house scarce resource and capability to make optimal decision to improve productivity. Leiblein, Reuer and Dalsace (2002) posits that make or buy with company governance can create technology performance. While Canez, Platts and Roberts (2000) discus make or buy framework on manufacturing industry span from technology and manufacturing processes, costs, scm and supports systems. While make or buy itself can see as multidisciplinary problem but long term cost driven always major factor to attribute.

As strategic decision with high implication, make or buy decision involved with assessment of company resource and capabilities initial position (Saudi, 2018). These assessment should carried on continual basis to measure how fast company can match market requirement to show survival ability. A close match between company resource and capabilities with uncertain market environment will define who the winner (Teece, Pisano and Shuen, 1997).

Framework to help make or buy decision in 1970 with price as primary factors and additional factor like delivery and service, today has been developed to include factor core competence (Hamel and Prahald, 1990, Barney, 1991), product characteristics, risk, economic, vertical integration, competition, intellectual property, and environment). Classical make or buy decision based on economic as suggest by Tompkins (2010) as show in figure 2.

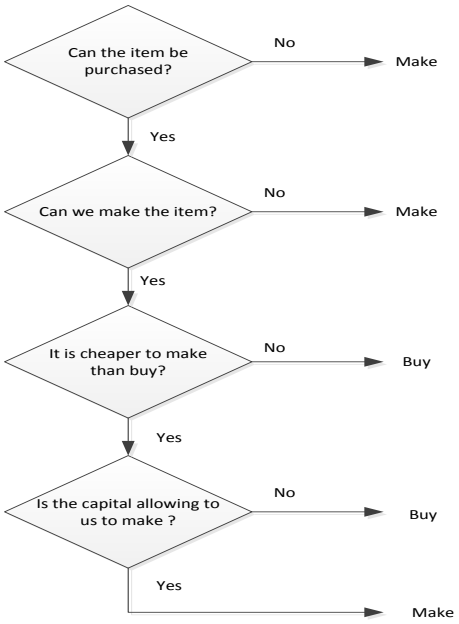

Figure 2:*Make or Buy Decision Process (Tompkins, 2010)*

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III. FRAMEWORK

To make better decision on make spare parts using 3d printing or buy to vendors, we proposed framework that include multi factor as follows:

Table 1:*Make or Buy Framework 3D Print Spare Parts*

Aspect	Factor	Item
Product	Quantity	Volume
		Frequency
		Uncertainty
	Physical Characteristics	Strength
		Material (Plastics/Metal)
		Surface Finish
		Size (Big/Small)
Supplier	Leadtime	Procurement/Production lead time
		Delivery leadtime
Cost	Fixed Cost	Investment cost
	Variable cost	Acquisition/Production Cost
		Maintenance Cost
Capabilities	Skill	3D Design
		CNC operation
Risk	Supply	Supply market risk (foreign sourced)
		Transportation Risk
		Availaibility alternative supplier
	Production	Quality
		Reliability
		Utilization
	Intellectual property	Intellectual property rights
	Core capabilities	In-house / buy
Business	Attractiveness	In-house / unattractive
	Competitive Positioning	Critical/Non spare parts
	Industry dynamics	Supply controlled by competitor
		Supply partnership
	Technology	Rate of change

This framework includes business aspect on 3d printing investment by company and the alignment their business strategy and evaluation of external aspect of industry and technology dynamic. Assessment this make or buy decision making framework can be achieved using basic scoring 0-100 or using analytical hierarchy process (AHP) (Saaty, 1990).

IV. CASE STUDY AND DISCUSSION

We invite three companies to discuss application 3d printer at their maintenance workshop to make certain spare parts for machine operation, and discussion attend by maintenance manager level. Companies representing the manufacturing sector in the textile sector in Cimahi (A), pharmacy (B) and machining both in Bandung (C).

Table 2:*Sample Companies*

	Company A	Company A	Company A
Number Employee	1200	350	75
Manufacturing Type	Make To Stock	Make To Stock	Make To Order
Product Orientation	Export	Export/Local	Local
Production Capacity	High	Medium	Low

Before discussion we play some video about current 3d printing technology to give same insight on possibility application at their maintenance workshop. Using framework above we ask every participants on what key decision

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lead to make spare parts incorporating 3d printing technology and result we summarize on table 3 (Jabarullah et al., 2019).

Table 3:*Summary Discussion with Industries*

Aspect	Factor	Item	A	B	C
Product	Quantity	Volume	Below 20 units		
		Frequency	Low for preventif maintenance		
		Uncertainty			
	Physical Characteristics	Strength	Depend on usage		
		Material (Plastics/Metal)	Plastics		Metal
		Surface Finish	Low Detail	High Detail	
		Size (Big/Small)	Small		
Supplier	Leadtime	Procurement/Production lead time	Production leadtime as low as half procurement lead time		Cannot estimate
		Delivery leadtime	Fast		
Cost	Fixed Cost	Investment cost	Low		Medium
	Variable cost	Acquisition/Production Cost	30-40% buying parts		40-70% buying parts
		Maintenance Cost	Low		
Capabilities	Skill	3D Design	Capability can be reach within month after training 3D CAD.		
		CNC operation	Not Available		In House
Risk	Supply	Supply market risk (foreign sourced)	Low		High
		Transportation Risk	Low		
		Availaibility alternative supplier	High		
	Production	Quality	High		
		Reliability			
		Utilization	Low		
	Intellectual property	Intellectual property rights			
	Core capabilities	In-house / buy	Buy		In House
Business	Attractiveness	In-house / unattractive	In House		
	Competitive Positioning	Critical/Non spare parts	Non critical spare parts		
	Industry dynamics	Supply controlled by competitor	For simple spare parts, many supplier can supply		
		Supply partnership	AdHoc		Medim
	Technology	Rate of change	Low		

We find that application 3d printer on make spare parts in house all participants agree that production cost should lower than buying at 20-60% due cutting expense in logistic cost to procure also low volume and frequency to support preventive maintenance function especially at textile and pharmaceuticals industry same as Svensson and Tunborg (2017). The main reason to use on non-critical spare parts are skepticism whether 3d printed parts as strong as injection molding products (plastics products) or casting and machining products (metal products).

All company understand that parts strength can be improve overtime as learning process deepen, but gambling on sustainability operation cannot be accepted without proper lab evaluation. Moreover the capability to support 3d printer as new technology in their maintenance workshop can be reach fast because availability engineer with knowledge 2D CAD software make learning curve to design 3d printed parts not too steep. They aware 3d printer technology will arrive and they have to prepare to adopt and making adjustment to their manufacturing process in small or large scale depend on degree of customization of their products as part to get sustainable advantage (Teece, et.al, 1997). Major problem they face are risk during first period adoption high failure rate and quality problems, and eventually will be cover after some period usage because increasing capabilities by gaining on new knowledge of 3d printing.

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V. CONCLUSION

Spare parts inventory become problem if low availability and long to procure impact on machine availability and productivity. In some case if spare parts criticality and physical property can be assessed, 3d printing can be viable alternatives instead procuring. Using this framework can help to asses whether procure or print spare parts in manufacturing industry to achieve machine availability and productivity.

Case study present us that industry basically will adopt these technology to produce spare parts for their machinery as long as low volume and frequency. Major risk in adoption 3d printing technology to produce spare parts are quality and reliability due to early adoption and this risk will reduce after gaining enough knowledge to create new capabilities.

Future research to understand more key adoption 3d printing technology on industry are dealing risk with benefit of adoption and change in supply chain structure as some vendor will be reduce.

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