Measuring the Effect of 3D Printing Machinery on Technology Management

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***Abstract*--Three-dimensional (3D) printing technology has arrived and is changing a philosophy of "management." A 3D-printed product is made from a powder or resin and can virtually shape any item from a digital graphics file. This new printing device, however, poses several unforeseen questions. The 3D printing technology calls for time and cost considerations. Once a private firm actually begins to operationalize the new technology, it will have to measure both merit and demerit in terms of a 'before-and after adaptation' perspective, in addition to a future prospect of further advantages the device might bring. Similarly, perhaps this is the most important, the use of this new technology might part away with the significant role and function of the core technology in production of different matters. Considering these topics, this study attempts to focus on the 3D printing technology and its influence on technology management. It specifically discusses the impact of 3D printing technology applied to manufacturing companies on their cost, time, quality and activities. To answer this question, a cost structure is developed using the IDEF0 method. The cost calculation is also considered using the Cost-Matrix method. After making model and matrix, possibilities are shown as research collaborators and outsourcing selection to organize with the concept of technology management. Through these analyses, problems are clarified, and the discussions indicate the results of introducing 3D printing technology, R & D innovation, and technology management.**

I. INTRODUCTION

In the competitive manufacturing industry, understanding the cost structure and the core technology is very important. Moreover, sales and profits are affected by changes in costs, depending on the setting, structure, and management.

Against this backdrop, three-dimensional (3D) printing technology has arrived, and it is changing the philosophy of "management." For example, GE [11] has gradually withdrawn from the financial field, while the company has been once again seeking a new entry to a manufacturing industry arena. The firm has termed this new direction as "Industrial Internet." Under this concept, products and software are connected each other by internet and these can be managed from a distance. By using the internet and 3D printing technology, companies no longer need to gather their manufacturing bases [1] [5] [13]. They install the 3D factory near users or set it in a land value cheap place. The total consequence will be that the philosophy of management, which essentially deals with allocation of manpower, goods and capital, would have substantially become reconsidered.

This technology allows the 3D replication of a solid object and can shape virtually any item from a digital graphics file [2]. A 3D-printed product is made from a powder or resin. The range of applications for this manufacturing technology is extensive and includes the automobile industry, consumer electronics, medical organs, and architectural models [20] [25] [29]. 3D printing technologies are the topic of many papers and business and industry reports. Stratasys [31] debates the choice between in-house 3D printing and outsourcing. They discuss the difference in time, costs, and management issues. Rayna and Striukova [27] report that 3D printing technology creates "business model innovation" for manufacturing and argues the strengths from the "value proposition," "value delivery," and "value capture" standpoints. These reports, however, do not define the relationship between 3D printing technology and technology management. We need to know more regarding the process and management decisions that include 3D printing.

Considering the topic of process management, this study focuses on 3D printing technology and its influence on technology management in manufacturing industries. It specifically discusses the impact of 3D printing technology on manufacturing companies in terms of cost, time, process activities, and technology management.

II. THE PREVIOUS STUDY ABOUT THE COST, PROCESS, TECHNOLOGY MANAGEMENT, 3D PRINTING POSSIBILITY AND THIS STUDY'S APPROACH

At first, numerous studies about cost management are focused. Historically, ABC (Active Based Cost) [22] and ABM (Active Based Management) [6] [10] were applied to numerous companies. These conventional ABC and ABM methods are able to use a variety of solutions to understand costs. However, they do not provide clear definitions about activities. In addition, the calculation step for each cost is not shown [6]. Therefore, this study clarifies each activity's elements through the IDEF0 process modeling method [8] [17].

The IDEF0 method is useful for distinguishing the activities through a drawing base [19] [34]. They have many researches attention to the cost management with the IDEF0 method [4] [26]. Numerous studies paid attention to cost management using the IDEF0 method and the IDEF0 method is useful for distinguishing activities through a figure base. However, these studies focus on only "one" activity typically in the manufacturing process, which has numerous processes that interrelate among the activities. Consequently, each cost related to the activities' interface, which manages the input and output of the activities, constraints, and time, needs to be discussed and clarified. Further, these studies did not focus on the possibility of 3D printing. Research using IDEF0 process modeling method also does not identify a specific field of study regarding technology management. Further investigation has found Saito's research [28] on the strength of manufacturing process technology, which analyzes three items: technological importance, technological maturity, and competition against another company. This research is very useful for a conventional or old company. Van der Zee and Jong [32] are also discuss the importance of the technology management for IT field. Several case studies, which are a bank and a food retailer, applied to the method of the Balanced Scorecard and discuss the importance of the management views. Banbury et al. [3] and Wan et al. [33] are also discuss the importance about technology management.

It does not, however, use IDEF0 analysis and is insufficient for a 3D printing company. The ideal process should consider the cost as well as technological importance.

In contrast, numerous studies provided approaches that focused on 3D printing. They were dedicated to the possibility of printing [9], focused on efficient ways to print [35], and discussed the cost effect [16]. Previous studies failed to identify the influence of 3D printing technology's activities on cost, the management process, and the value added.

Therefore, Nakamura et al. [23] [24] examined the possibility of 3D printers in terms of manufacturing processes, product inventory, and product yield. To clarify the process, they analyzed process flows using IDEF0 and calculated a cost structure. Their study attempted to connect IDEF0 and the cost structure. However, the object of IDEF0 is a hypothetical company, and not discussing about the technology management issues.

Consequently, this study compares a typical manufacturing process in a real wireframe company in which a 3D printing technology is introduced. The IDEF0 method is introduced to bring about clarity in the process. According to the process, the cost matrix method calculates costs related to IDEF0. The core technology matrix also serves to analyze and extract the core technology in the process. Through these analyses, the cost structure is made clear in the process flow. Moreover, the analysis recognizes the strength of a company from the perspective of current technology and future prospects by examining a situation in which a real manufacturing company introduces a 3D printing technology. Finally, technology management issues are considered and studied.

III. USING THE IDEF0 AND THE COST AND CORE TECHNOLOGY CALCULATION MODEL

A. Using the IDEF0

To clarify the process activities involved with human resources, products, and equipment, this study introduces the concept of the IDEF0 for the manufacturing process model (Figure 1). The box in Figure 1 indicates an activity, such as "manufacturing process" or "delivery." The arrows indicate the flow of materials, the design file, the product, and so on. The inputs enter from the left side of the box ($I^n_{i(n)}$) and the outputs exit from the right side of the box ($Y^n_{y(n)}$). Inputs are transformed into outputs through the activity. Outputs created include data or objects produced by the activity. Arrows entering the box from the top represent controls (C) that specify the conditions required for the activity to produce correct outputs. Arrows connected to the bottom of the box represent mechanisms ($M^n_{m(n)}$). Upward pointing arrows identify support for the execution of the activity. Activities are linked through the input and output arrows, and a generic term of these four arrows is called an "ICOM." The activity also clarifies the hierarchical characteristic and the nested structure of new activities, which explains the details of the activity.

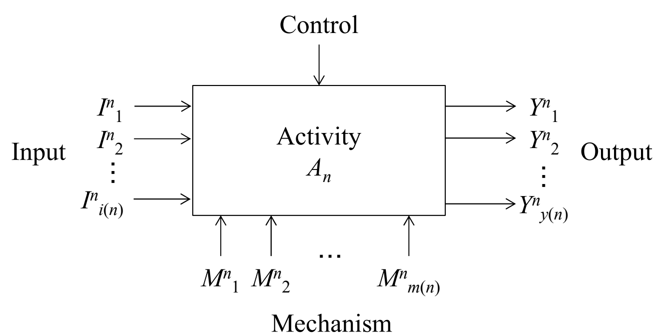

Figure 1: Activity of IDEF0

After clearing the activities through the IDEF0 method, each activity's cost calculates by using the cost matrix method. Core technology matrix also forms for identify the core technology in the process. In this approach, each activity's cost and technology is clearing through the calculation.

B. The cost matrix model

The cost matrix method is formed as follows:

$$
\begin{aligned}
C^n &= \left[c\left(Y^n_1\right) \;\; c\left(Y^n_2\right) \;\cdots\; c\left(Y^n_{y(n)}\right) \right]^T \\
&= \left[Q^n \mid R^n \right] \left[\begin{array}{c|c} SQ^n & 0 \\ \hline 0 & SR^n \end{array} \right] \left[\begin{array}{c|c} E^{i(n)} - L^n & 0 \\ \hline 0 & E^{m(n)} - K^n \end{array} \right] \left[\begin{array}{c|c} U^n & 0 \\ \hline 0 & S^n \end{array} \right] \left[\begin{array}{c} I^n \\ \hline M^n \end{array} \right]
\end{aligned} \tag{1}
$$

n is the activity number.
C^n is the unit matrix of the cost.
$c(Y^n_{y(n)})$ is the cost of the output $Y^n_{y(n)}$.

This matrix calculates the cost of the products or the semi-manufactured products $Y^n_{y(n)}$ in activity An. Details of each matrix are as follows:

Q_n is the amount of material required to make $Y^n_{y(n)}$.

$$Q^n = \begin{bmatrix} q_{11}^n & q_{12}^n & \cdots & q_{1n}^n \\ q_{21}^n & q_{22}^n & \cdots & q_{2n}^n \\ \vdots & \vdots & \ddots & \vdots \\ q_{y(n)1}^n & q_{y(n)2}^n & & q_{y(n)n}^n \end{bmatrix} \quad (2)$$

$q^n{}_{ij}$ is the amount of material or semi-manufactured product j required to make semi-manufactured products or product i in activity An.

R^n is the operating time of material required to make $Y^n{}_{y(n)}$.

$$R^n = \begin{bmatrix} r_{11}^n & r_{12}^n & \cdots & r_{1m(n)}^n \\ r_{21}^n & r_{22}^n & \cdots & r_{2m(n)}^n \\ \vdots & \vdots & \ddots & \vdots \\ r_{y(n)1}^n & r_{y(n)2}^n & \cdots & r_{y(n)m(n)}^n \end{bmatrix} \quad (3)$$

$r^n{}_{ij}$ is the operating time of material or semi-manufactured products j required to make semi-manufactured products or products in activity An.

SQ_n is the rate of the material matrix depending on the requested size.

$$SQ^n = \begin{bmatrix} sq_1^n & 0 & \cdots & 0 \\ 0 & sq_2^n & \cdots & \vdots \\ \vdots & \vdots & \ddots & 0 \\ 0 & 0 & \cdots & sq_{y(n)}^n \end{bmatrix} \quad (4)$$

$sq^n{}_{ij}$ is the rate at which materials or semi-manufactured products j are used to make semi-manufactured products or products i depending on the requested magnitude of activity An. Final product changes are made according to customer requests, which create variations in the amount of materials, semi-manufactured products, and human resource consumption.

SR^n is the rate of operating time matrix depending on the requested size.

$$SR^n = \begin{bmatrix} sr_1^n & 0 & \cdots & 0 \\ 0 & sr_2^n & \cdots & \vdots \\ \vdots & \vdots & \ddots & 0 \\ 0 & 0 & \cdots & sr_{m(n)}^n \end{bmatrix} \quad (5)$$

$sr^n{}_{ij}$ is the rate of at which material or semi-manufactured products j required to make semi-manufactured products or products i depending on the requested magnitude of activity An. Final product changes are transformed according to customer requests, which create variations in the amount of materials, semi-manufactured products, and human resource consumptions.

L^n is the rate of the material loss.

$$L^n = \begin{bmatrix} l_1^n & 0 & \cdots & 0 \\ 0 & l_2^n & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & l_{i(n)}^n \end{bmatrix} \quad (6)$$

l^n is the rate of the material loss for each output, which is calculated as the rate of the material yield from the unit matrix subtracting L^n.

K^n is the rate of the operating loss.

$$K^n = \begin{bmatrix} k_1^n & 0 & \cdots & 0 \\ 0 & k_2^n & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & k_{m(n)}^n \end{bmatrix} \quad (7)$$

$k^n{}_k$ is the rate of the operating loss for each output, which is calculated as the formal operating time from unit matrix subtracting K^n.

U^n is the material cost per unit.

$$U^n = \begin{bmatrix} u_1^n & 0 & \cdots & 0 \\ 0 & u_2^n & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & u_{i(n)}^n \end{bmatrix} \quad (8)$$

$u^n{}_k$ is the cost per unit of material or semi-manufactured products k in activity An.

S^n is the operating time per unit.

$$S^n = \begin{bmatrix} s_1^n & 0 & \cdots & 0 \\ 0 & s_2^n & & \vdots \\ \vdots & & \ddots & 0 \\ 0 & \cdots & 0 & s_{m(n)}^n \end{bmatrix} \quad (9)$$

$s^n{}_k$ is the operating time per unit of the equipment or stuff k in activity An.

I^n is the amount of the material flow.

$$I^n = \begin{bmatrix} I_1^n & I_2^n & \cdots I_{i(n)}^n \end{bmatrix} \quad (10)$$

$I^n{}_k$ is the amount of material or semi-manufactured products k required to execute the activity An at one time.

M^n is the number of the equipment.

$$M^n = \begin{bmatrix} M_1^n & M_2^n & \cdots M_{m(n)}^n \end{bmatrix} \quad (11)$$

$M^n{}_k$ is operating time of the equipment or stuff k required to execute the activity An at one time.

C. The core technology matrix model

The core technology matrix model is formed as follows:

$$T^n = \left[t\left(Y_1^n\right)\ t\left(Y_2^n\right) \cdots t\left(Y_{y(n)}^n\right) \right]^T$$

$$= \begin{bmatrix} im_{11}^n & ma_{12}^n & co_{13}^n \\ im_{21}^n & ma_{22}^n & co_{23}^n \\ \vdots & \vdots & \vdots \\ im_{y(n)1}^n & ma_{y(n)2}^n & co_{y(n)3}^n \end{bmatrix} \begin{bmatrix} w_1{}^n \\ w_2{}^n \\ w_3{}^n \end{bmatrix} \qquad (12)$$

T^n is the unit matrix of the technological value.
$t(Y^n{}_{y(n)})$ is the technological value of the output $Y^n{}_{y(n)}$.

This matrix calculates the technological importance of products or semi-manufactured products evaluated from $im^n{}_{y(n)}$ (from lowest 1 to highest 5 points on the Likert scale). This value indicates the hierarchy of importance in the process flow.

- $ma^n{}_{y(n)}$ (from lowest 1 to highest 5 points on the Likert scale) is a factor of technological maturity. This is the technological life cycle.
- $co^n{}_{y(n)}$ (from lowest 1 to highest 5 points on the Likert scale) is a factor of the technological competition in the market.
- $w^n{}_i$ ($\sum w^n{}_i = 1$, $w^n{}_i \leq 1\ \forall i$, $i = 1, 2, 3$) is a weight among the former factors, which are importance, maturity, and competition.

Through these values, the score of technological importance is calculated. This value recognizes the activities that have the competitiveness, potential for growth, and future prospection through the IDEF0 method.

IV. APPLICATION FOR COMPANY A

A. About Company A and its IDEF0

Applied manufacturing company, called “Company A,” engages in processes to make wires from plastic. They makes a parasitic wire for industrial product. Its wire uses for removing impurities.

Figure 2 illustrates the IDEF0 of Company A’s manufacturing process. The four important activities are as follows: A1 represents base fabric manufacturing, A2 represents the stock process for the base fabric manufacturing, A3 represents the finished product, and A4 represents the delivery process. In detail, A1 represents the process that transforms plastic into grainy wire. The plastic is supplied by other companies, which develop a delivery time schedule plan. The grainy wire is called the “base fabric net.” A3 represents the finished product ordered from a customer, and A4 represents the delivery activity to the customer, including packaging.

Figure 3 illustrates the nested structure of the A1 activities. At activity A11, raw materials are checked for their strength, length, density, and other specifications. Activity A12 represents warping, which is a preparation process for looming the wire using a looming machine. The raw material is prepared into a wire rolled by a tubular. Activity A13 represents weaving the wire through the looming machine. Activity A14 represents the heat set process in which the weaving wire becomes the base fabric net through heating.

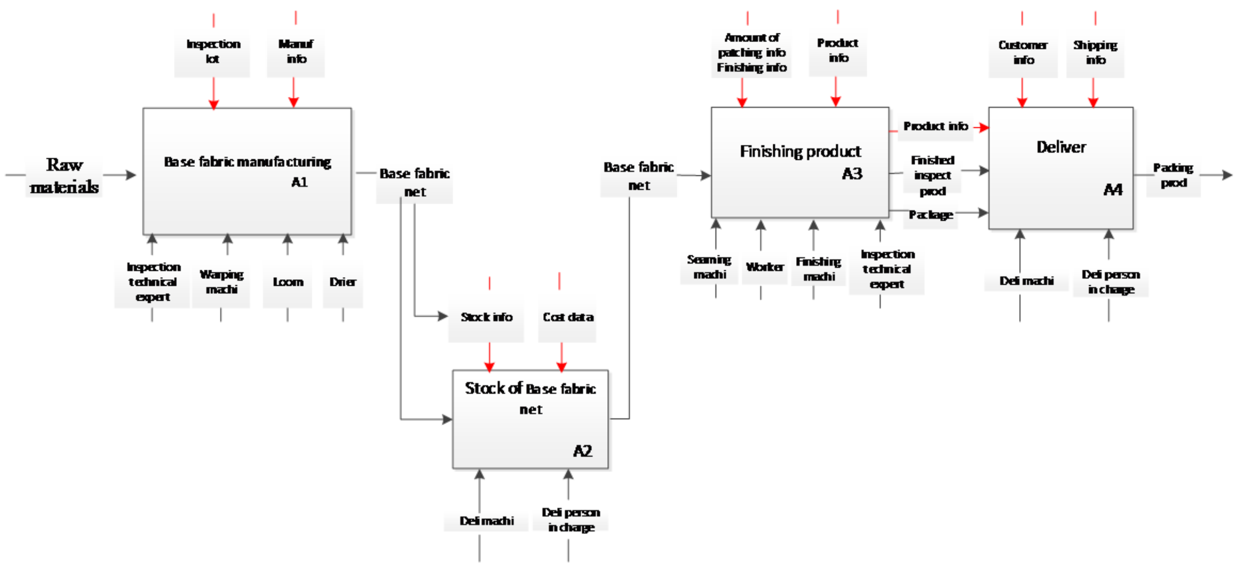

Figure 2: Typical manufacturing process

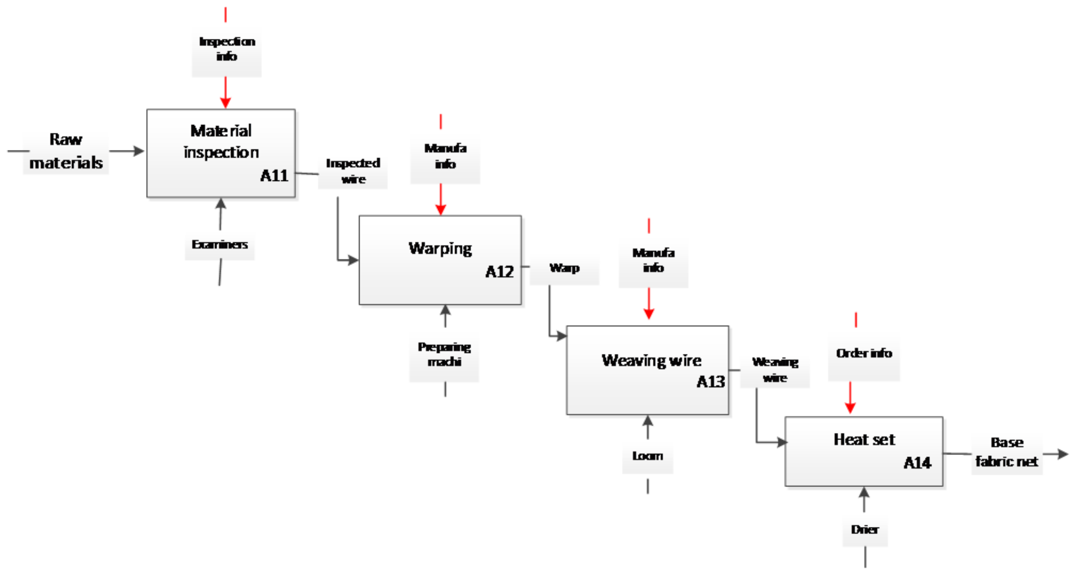

Figure 3: Nested structure of A1 activity

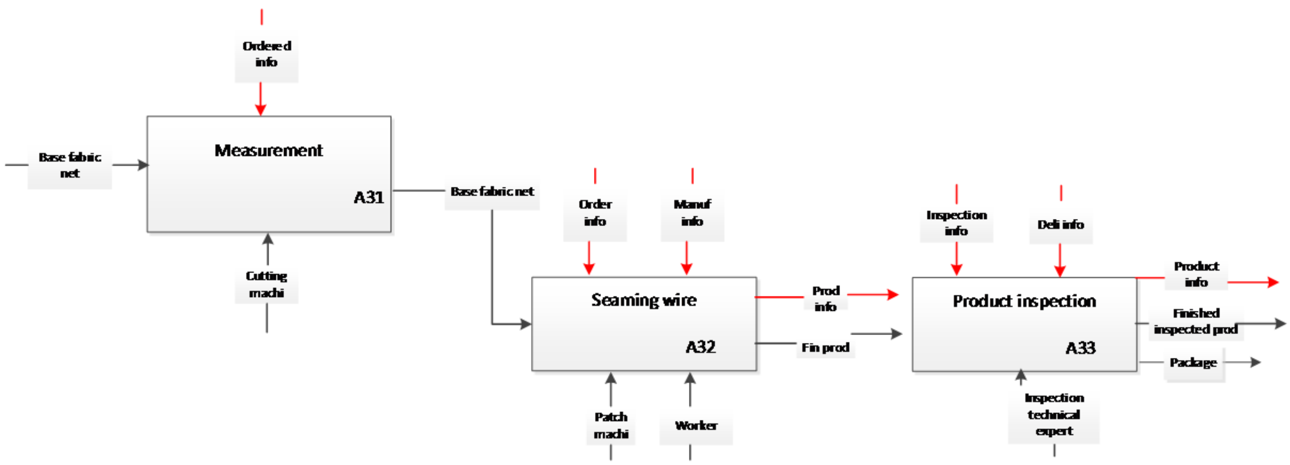

Figure 4: Nested structure of A3 activity

Figure 4 illustrates the nested structure for the A3 activities. The A31 activity, which represents measuring, is a cutting process according to the customer's order information. Activity A32, which involves a seaming wire, represents poaching the wire with human hands (Figure 5). Company A has a significant problem executing this activity, which takes a long time to process, generates high costs, and is based on order information for net size and volume. Ordering the product to delivering the product to the customer requires significant lead-time. Consequently, a large volume of base fabric nets is stocked at processing activity A2, "stock for base fabric net."

Next, 3D printing technology is applied to Company A, as shown in Figure 6. In this case, three activities occur: A1 represents design, A2 represents the 3D printer's molding, and A3 represents the delivery process.

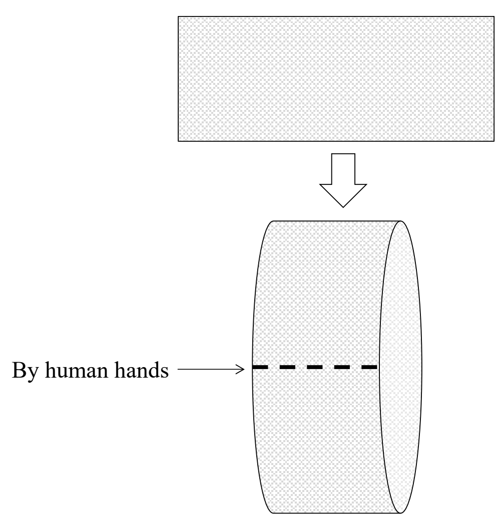

Figure 5: Activity A32

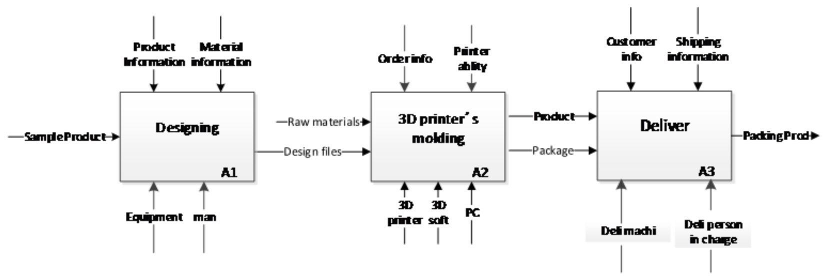

Figure 6: 3D process

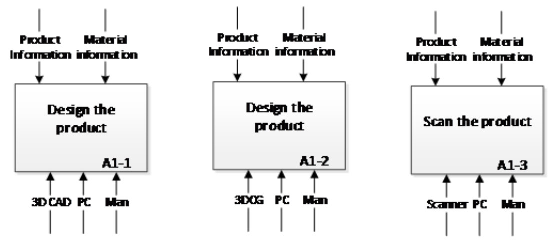

Figure 7: Alternative processes of the 3D A1 process

In this case, design uses three methods (Figure 7). First, the product is designed using a 3D computer-aided design (CAD). Second, a 3D computer graphic is used. Finally, a 3D scanner scans a sample product or a final molded product and converts a 3D spatial image to a digital file. The digital file flows from the output of A1 to the input of A2.

Using the digital file and the raw materials, activity A2 prints the finished product using the 3D printer. The printing speed depends on the 3D printer's output size, buildup speed, and graphic mode. There are different types of the 3D printer. In this study, equations (4) and (5) are applied to the output cost and time according to the printer's ability.

B. Calculating and studying the cost of typical manufacturing and 3D printing processes

In this chapter, each activity's cost is calculated using the cost and core technology matrix. The initial data and the parameters are used in the calculation. Table 1 provides the initial data on the rate of material loss, operating cost, and time per unit, and determines the 3D printer's ability.

Equipment processing costs, such as warping costs, are calculated as depreciation divided by the equipment's operating time throughout the year. Equipment time influences the equipment's ability per hour. Human processing cost is a fixed hourly wage for each activity. Setting the molding time is difficult because of the various types of 3D printers. Each printer's ability is different with respect to molding time, resolution, lamination pitch, and other characteristics. This study assumes that the 3D printer's ability is decided on by the input data, including width, depth, and height. As a result, the following formula calculates the molding time.

TABLE 1: INITIAL DATA

A unit cost		The rate of yield	
Wire cost per g	500	Inspected wire	1.000
Package cost	1,000	Warping	1.000
Processing costs per mm		Weaving	0.980
Material inspection cost	20,000	Heat set	1.000
Warping cost	100,000	Base fabric	1.000
Weaving cost	100,000	Seaming	0.950
Drier	50,000	Measurement	1.000
Delivery machine	50,000	Finished product inspection	1.000
Stock hour cost	1,000	Total rate of yield	0.931
Seaming cost (machine)	200,000	3D Molding time	
Seaming cost (human)	1,000		Partial regression coefficient
Measurement cost	20,000	Variable	
Finished product inspection cost	20,000	Parameter α	0.194
		Parameter β	0.755
		Parameter γ	0.202
		Constant term A	-3.930

$$\begin{pmatrix} t_1 \\ t_2 \\ \vdots \\ t_n \end{pmatrix} = \begin{pmatrix} A_{11} & A_{12} & \cdots & A_{1n} \\ A_{21} & \ddots & & \vdots \\ \vdots & & \ddots & \vdots \\ A_{m1} & \cdots & \cdots & A_{mn} \end{pmatrix} \times \begin{pmatrix} w_1^{\alpha_1} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & w_n^{\beta_n} \end{pmatrix} \times \begin{pmatrix} d_1^{\beta_1} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & w_n^{\beta_n} \end{pmatrix} \times \begin{pmatrix} h_1^{\gamma_1} & 0 & 0 \\ 0 & \ddots & 0 \\ 0 & 0 & w_n^{\gamma_n} \end{pmatrix} \quad (13)$$

A_{mn}, α_n, β_n, and γ_n are the parameters assumed in a multivariate analysis. Measured value refers to real 3D printing time for a ProJet 5500. Therefore, printing time (t_n) must be forecasted from real printing data. In this manner, the operating and 3D printing time and cost assist in calculations using the cost-matrix method.

Table 2 lists each processing time taken to develop the final product assuming a width of 1,000 mm, depth of 10,000 mm, and height of 50 mm. Using the lists, total processing time of both the typical manufacturing process and the 3D process can be estimated.

TABLE 2: PROCESSING TIME

Usual process	
Inspection	5.000
Warping cost	10.000
Weaving cost	3.000
Hear set	2.000
Delivery machine	1.000
Seaming machine	10.000
Seaming machine	7.500
Measurement	2.000
Fin-prod inspection cost	3.000
Stock	50.000
3D process	
3D molding time	5.768
3D design time	3.846

Table 3 presents a calculation process for the unit cost in A1's nested activity. The size of the wire is width 1,000 mm, depth 10,000 mm, and height 50 mm. It is the average size of the industrial wire. The left column represents "Activity." "ICOM" and "Content" are from the IDEF0. "Total price" represents the material cost of the input and output of the "Contents." The calculation of the total price is the sum of "Quantity after loss" multiplied by "Unit price per quantities." The total cost of the processing price is calculated using the mechanism in Table 3. The total cost of the processing time is calculated multiplying the processing time from Table 2 by the "Unit price per processing." For example, A12's warping process used 500 g of wire input, which changed to a net 2,000 mm^2 through the activity. From this output, the material cost was 500 g of wire multiplied by 500 yen from Table 1, or 250,000 yen. To calculate the unit cost, the 250,000 yen was divided by 2,000 mm^2 of net warping, for 125 yen, which goes to A13's input unit cost per quantity. To determine net warping, a warping machine needs to operate for five hours. The machine cost was 500,000 yen and the cost to prepare the wire for the machine was 1,000 yen. Finally, the total processing cost was 500,000,000 yen for activity A12, and 500 yen was the unit cost for each occurrence of the activity.

Table 4 indicates the 3D manufacturing calculation process through a selection of the case of "A1-3." In the A1-3 activity, the mechanism needs 3.85 hours of activity to scan the product.

TABLE 3: ACTIVITY A1'S CALCULATION PROCESS OF UNIT COST

A1:Base fabric Manufacturing	A11:Material inspection	Output	Inspected wire	100 g	100 g					
		Mechanism	Examiners					2,500 h	20,000 ¥/h	50,000,000 ¥
		Control	Inspection info	100 g						
		Input	Raw material	100 g		500 ¥/g	50,000 ¥			
		Total					50,000 ¥			50,000,000 ¥
		Unit cost with loss					500.00 ¥			500,000.00 ¥
	A12:Warping	Output	Warping net	2,000 mm2	2,000 mm2					
		Mechanism	Warping machine					2,500 h	100,000 ¥/h	250,000,000 ¥
		Control	Manufacturing info							
		Input	Inspected wire	500 g	500 g	500 ¥/g	250,000 ¥		500,000 ¥/h	250,000,000 ¥
		Total					250,000 ¥			500,000,000 ¥
		Unit cost with loss					125.00 ¥			250,000.00 ¥
	A13:Weaving wire	Output	Weaving wires	1,500 mm2	1,470 mm2					
		Mechanism	Loom					1,500 h	100,000 ¥/h	150,000,000 ¥
		Control	Manufacturing info							
		Input	Warping net	1,500 mm2	1,500 mm2	125 ¥/mm2	187,500 ¥		250,000 ¥/h	375,000,000 ¥
		Total					187,500 ¥			525,000,000 ¥
		Unit cost with loss					127.55 ¥			357,142.86 ¥
	A14:Heat set	Output	Base fabric net	500 mm2	500 mm2					
		Mechanism	Drier					1,000 h	50,000 ¥/h	50,000,000 ¥
		Control	Manufacturing info							
		Input	Weaving wires	500 mm2	500 mm2	128 ¥/mm2	63,776 ¥		357,143 ¥/h	178,571,430 ¥
		Total					63,776 ¥			228,571,430 ¥
		Unit cost with loss					127.55 ¥			457,142.86 ¥

TABLE 4: 3D MANUFACTURING CALCULATION PROCESS IN CASE OF THE "A1-3."

Activity		ICOM	Content	Quantity	Quantity after the loss	Unit price per quantities	Total price	Processing time	Unit price per processing	Processing price
		Output	Design files	1 byte	1					
		Mechanism	Scanner					115 h	35 ¥/h	4,002 ¥
			PC					115 h	9 ¥/h	1,000 ¥
A1:Making the design	A1-3:Scan the product		Man					115 h	1,000 ¥/h	115,256 ¥
		Control	Product Information							
			Material Information							
		Input	Sample Product	1 m	1					
		Total								119,258 ¥
		Unit cost with loss								119,257.90 ¥
		Output	Product	100 mm	100 mm	500 \/g	50,000 ¥			
			Package							
		Mechanism	3D printer					173 h	347 ¥/h	60,029 ¥
			3D soft							
A2:3D printer's molding			PC							
		Control	Order information							
			Printer ability							
		Input	Raw material	500 g		10,000 ¥/g	5,000,000 ¥		119,258 ¥/h	59,628,951 ¥
			Design files							¥
		Total					5,000,000 ¥			59,688,980 ¥
		Unit cost with loss					10,000.00 ¥			596,889.80 ¥
		Output	Packing product	100 mm	100 mm					
		Mechanism	Delivery machine					10 h	260 ¥/h	2,604 ¥
			Delivery person in charge					1 h	1,000 ¥/h	1,000 ¥
		Control	Customer information							
A3:Delivery			Shipping information							
		Input	Finished inspected product	100 mm		1,000 ¥/mm	100,000 ¥			
			Product information							
			Package	1 m		100 ¥/mm	100 ¥			
		Total					100,100 ¥			3,604 ¥
		Unit cost with loss					1,001.00 ¥			36.04 ¥

TABLE 5: TOTAL MATERIAL PROCESSING COST

Cost item	Material cost	Processing costs	Total
Material cost			
Wire	134.26		134.26
Package	10.00		
Processing costs			
Inspection cost		134,264.23	134,264.23
Warping cost		134,264.23	134,264.23
Weaving cost		107,411.39	107,411.39
Loom cost		105,263.16	105,263.16
Delivery equipment cost		105.26	105.26
Delivery person in charge		105.26	105.26
Seaming cost (huMan)		328.95	328.95
Measurement cost		40,000.00	40,000.00
Finished prod inspection cost		30,000.00	30,000.00
Subtotal	144.26	551,742.48	551,886.74
Total	144.26	551,742.48	551,886.74

Cost item	Material cost	Processing costs	Total
Material cost			
Resin	500		500
Package	100		100
Processing costs			
Design soft cost		4001.94	4001.94
Design equipment cost		1000.49	1000.49
Designer's cost		115255.96	115255.96
Molding cost		600.29	600.29
Delivery equipment cost		26.04	26.04
Delivery huMan cost		10	10
Subtotal	600	120894.72	121494.72
Total	600	120894.72	121,494.72

Table 5 indicates the total material cost and processing cost for width 1,000 mm, depth 10,000 mm, and height 50 mm. The material cost is calculated using the cost matrix method, which produces a material cost subtotal of 144.26 yen in the typical process. The processing cost subtotal is 551,742.48 yen, resulting in a total manufacturing process cost of 551,886.74 yen for the typical process. For the 3D process, the total cost is 121,494.72 yen. Therefore, the typical manufacturing process has a higher cost than the 3D technology process. In the detailed cost analysis, the seaming cost incurred by humans is 328.95 yen. The seaming wire process of the typical manufacturing process is time consuming if the required final product volume is produced; consequently, it requires more labor and equipment processing hours. This activity also incurs significant production costs, which change depending on the size of the final product.

Table 6 provides the assessment outputs of the core technological value. The value of each activity is the input. For example, activity A13 is a very important stage with respect to the finished product. It indicates that the output is an important value, 5 in this case, which is the highest possible score. In the same way, the maturity value is 4, and the competition value is 5. To sum it up, activity A13 is an activity of high competitive power and importance in comparison with other companies. Through this method, the importance of the activities is evaluated.

After the weights of the three factors are set—importance is 0.4, maturity is 0.1, and competition is 0.5—the matrix is calculated. As a result, process A32 has a high score in the usual process. In the 3D printing process, processes A1 and A2 have the same importance through technological importance.

TABLE 6: THE CORE TECHNOLOGICAL VALUE IN EACH ACTIVITY

Activity (Usual)		Important	Maturity	Competition	Technological Importance
A1:Base fabric Manufacturing	A11:Material inspection	2	2	2	2
	A12:Warping	3	4	4	3.6
	A13:Weaving wire	5	2	5	4.7
	A14:Heat set	2	2	3	2.5
A2:Stock of Base fabric net		5	4	3	3.9
A3:Finishing product	A31:Measurement	1	2	1	1.1
	A32:Seaming wire	5	4	5	4.9
	A33:Product inspection	2	4	4	3.2
A4:Delivery		2	2	2	2

Activity (3D)	Important	Maturity	Competition	Technological Importance
A1:Making the design	5	5	5	5
A2:3D printer's molding	5	5	5	5
A3:Delivery	2	2	2	2

C. Managerial Consideration

In this chapter, outputs from the calculation of the cost and core matrix are consider and discuss the possibility in the future form the managerial points of view.

Table 7 shows the outputs from the calculation of the cost and core matrix. The total price is the total cost of materials. The processing price is the cost of the time transaction. Technological importance is the value from the core matrix. From this table, it is possible to discuss each process of problems, strengths, etc.

In the usual scope of activities, process A32 has the highest cost because it is performed by human hands and thus requires considerable labor cost. Technological importance also has a high score in the process. This means that A32 is the core process in the company and is its best strength against competitors. A32, which is the core manufacturing process for Company A, has an overwhelming advantage over its competitors. If this is the case, this strength should stay with the firm, although other dimensions which may not possess competitive edges could be outsourced.

TABLE 7: OUTPUTS FROM THE CALCULATION OF THE COST AND CORE MATRIX.

Activity (Usual)		Total price	Processing price	Technological Importance
A1:Base fabric Manufacturing	A11:Material inspection	50,000	50,000,000	2.00
	A12:Warping	250,000	500,000,000	3.60
	A13:Weaving wire	187,500	525,000,000	4.70
	A14:Heat set	63,776	228,571,430	2.50
A2:Stock of Base fabric net		63,776	228,671,430	3.90
A3:Finishing product	A31:Measurement	67,132	20,000,000	1.10
	A32:Seaming wire	153,061	1,549,186,432	4.90
	A33:Product inspection	13,426	3,000,000	3.20
A4:Delivery		154	36	2.00

Activity (3D)		Total price	Processing price	Technological Importance
A1:Making the design	A1-1:Design the product		119,258	5.00
	A1-2:Design the product		119,258	
	A1-3:Scan the product		119,258	
A2:3D printer's molding		5,000,000	59,688,980	5.00
A3:Delivery		100,100	3,604	2.00

In the 3D printing scope of activities, A1's design process and A2's molding process have the highest scores. In A1 of the 3D process, the design is very important. Because, it decides the raw material usage, the processing time and quality level by the design. As a result, it is higher the importance of the design.

When it comes to 3D printing molding, the printing time is the most important aspect to the finished products. 3D printing history is shallow and its technology is not enough to satisfy for users. Put differently, the stacking pitch decides the printing performance because this pitch decides the printing time. Currently, depending on the printer, it takes one hour to make a 10-cm-tall figure using a 3D printer. However, technology is always improving. As one may recall, in the past, it took one hour to print text on a sheet of paper using a 2D printer. It is expected that future 3D printers will demonstrate improved performance, higher quality, and lower costs.

From the management perspective, a company can reconsider resource allocation when introducing 3D printing. For example, A4's delivery does not equal or better the competition's standards. So, the management can opt to reconsider this resource allocation. The other output is that A12 has a higher cost but is not relatively high in technological importance. As a result, the management may re-examine the option to cut costs on machinery. Through these discussions, process management and productivity are taken to a higher level through the entire investment.

Finally, from a management perspective, a strategic mechanism should be explored by which the core technology should remain as the central piece of manufacturing, while other components with less competitive powers would be taken care of by the 3D printing device. In Table 7 listed above, the A32 activities look highly important and stay competitive in Company A from technology management views. The A1 process, however, could be adopted and utilized by the 3D printing technology in other different places. What all issues would eventually come down to is: a new management decision ought to be made as to which part A32 should stay in human hands, while other sections could be processed by A1 using the 3D printing. This final decision reflects an important reexamination of the allocation of manpower, goods and capital. This discussion may help highlight a process problem, strength and weak points of the companies, and other concerns.

V. CONCLUSION

This study focuses on the possibility of 3D printing technology and discussed from the viewpoints of their cost, time, quality and activities. It makes clear to use the mothed as IDEF0 and cost and technological matrix. Applied to one of the wire frame company, the possibility and future prospect discuss about the results of introducing 3D printing technology, R & D innovation, and technology management.

As a result, this study provided the following outcomes: 1) an understanding of the cost structure for each activity in the real company, 2) a discussion of a typical manufacturing process and the introduction of the 3D printing process through a sensitive analysis, and 3) clarifying future discussions regarding the introduction of 3D printing technology.

Numerous areas exist for future research, including applications to other companies and using real numerical examples.

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