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An Economic Analysis of Water Pump QR Code Printing Method Considering RCP 4.5 Climate Change Scenario

Sang Han Lee, Chae Soo Kim
(Department of Smart Manufacturing Convergence System Engineering, Dong-A University, Busan, Republic of Korea)

Abstract: This shows a case study on economic analysis to determine the QR code marking method in pump product packaging process. In order to analyze the cost of the QR code marking for "in-store marking" and "source marking", it is necessary to predict the production amount. We analyzed the past data regarding production amount and precipitation. We found correlation of them, and developed a prediction equation for production quantity by regression analysis. RCP climate change scenario has been utilized to estimate the future precipitation for 5 years since 2020. We clarified that "Source Marking" is superior to "In-store Marking" in the view of total cost for QR code marking system for water pump production.

Key words: economic analysis; QR code; RCP; Pump
JEL codes: L600

1. Introduction

Generally, "stock is the product of all processes". Therefore, the optimization of inventory is an important issue for the company and a matter that must be kept in the future (E. K. Jang, 2012). W company, a water pump manufacturer, is experiencing fluctuating demand due to seasonal fluctuations and natural disasters, making it difficult to predict demand. W company's pump is composed of about 1,200 different product groups, so there is a need for efficient management. In addition, if there is a defect in the finished product, it may be possible to identify the cause or reopen the wrapping paper in order to distinguish the finished product inherent in the cause. In order to do this, a QR code is attached to the finished product wrapping paper, and a method of tracking and managing inventory through WMS (Warehouse Management System) is introduced. In general, introducing a logistics management system using QR code improves the reliability of system operation. By using QR code to register and manage the performance of packaging in real time in the workshop, the production performance can be grasped in real time, resulting in data collection and monitoring effect about 11% faster than the time input from PC. In addition, when QR code is used, the tags are scanned and managed by a Personal Digital Assistant when the product is shipped, which can reduce the time required for the shipment.

This study analyzes the economic feasibility to find a reasonable way to attach QR code to the package of pump products with a minimum increase in manufacturing cost. We will apply economic analysis and select

Sanghan Lee, Master, Department of Smart Manufacturing Convergence System Engineering, Dong-A University. E-mail: pighan44@gmail.com.
Chae Soo Kim, Ph.D. in Industrial Engineering, Professor, Department of Smart Manufacturing Convergence System Engineering, Dong-A University. E-mail: cskim@dau.ac.kr.

superior alternatives from the results. In the process of estimating the cost, the RCP4.5-based precipitation forecast is used to predict the pump output, and then the regression analysis is used to predict the output. In chapter 2 of this study, the overview and features of pump and barcode system are additionally reviewed and related literature studies are also introduced. In Chapter 3, various costs for economic analysis are estimated, and the estimated results are calculated using the future value method to calculate the economic value of the input cost. Finally, Chapter 4 introduces superiority alternatives derived from the analysis and describes additional research areas that will be needed in the future.

2. Overview of Pump and Barcode

2.1 Overview of Pump

A pump is a machine that receives kinetic energy from a prime mover, supplies velocity energy to a fluid and efficiently converts it into pressure energy to transfer the fluid from a low place to a high place, or from a low pressure to a high pressure.

A pump is needed to carry the fluid and overcome the resistance of the piping system. In pump systems at different fluid levels, this means overcoming geodetic head differences. Centrifugal pumps are the source of fluid flow because of their design and energy conversion scheme. Although there are various types, one common feature of all centrifugal pumps is that the fluid enters the impeller axially. The electric motor drives the pump shaft with the impeller attached. Water enters the impeller axially and is turned radially by the impeller blades. The centrifugal force affecting each fluid increases the speed and pressure as the water flows through the wing area. The fluid collects in the vortex casing after passing the impeller. The flow rate is slightly slowed down by the casing structure but the pressure is further increased by the energy conversion. The main components of the pump are the pump casing, the motor and the impeller. Pumps are heavily influenced by sales and production volume due to seasonal changes such as weather and flooding.

2.2 Overview of Barcode

Barcode represent letters and numbers by combining black bars and spaces of different thicknesses in specific forms in order to make the computer easier to read information (E. K. Jang, 2000). Barcode can be printed at a very low price by various printing techniques, and the size can be reduced and enlarged to suit a specific purpose, and the height of the bar increases the data margin (D. Y. Lee, 2011).

2.2.1 One-dimensional Barcode

One-dimensional barcode take the form of patterns arranged with black bars of various thicknesses and white space symbols. The bottom of the bar code contains 13 digits. The first three digits are the country identification code, which is marked as 880 in Korea. The next 4 digits are the company specific code, and the next 5 digits are the codes that the company assigned the manufacturer code to the company. The last single digit is a computer check digit that ensures that the bar code is correctly constructed, increasing the reliability of the KAN. Price is indicated separately (S. H. Park, 2011).

Figure 1 One-dimensional Barcode (Y. H. Lee, 2014)

2.2.2 Two-dimensional Barcode

One-dimensional barcode have the advantages of being relatively easy to generate and easy to display on various media, but have a problem in delivering specific product information because of their poor storage capacity. Two-dimensional barcode are flat barcode expressed in Braille or mosaic codes in both the horizontal and vertical directions. One-dimensional barcode can express information only in the horizontal direction, while two-dimensional barcode can express information in the horizontal and vertical directions, greatly improving information storage and throughput. Two-dimensional barcode have increased the amount and type of information that can be stored than one-dimensional barcode, and the recognition speed, recognition rate, and resilience have improved compared to the amount of information. In addition, it is not possible to modify or record additional information, but since paper is used as a medium to store a large amount of information, barcode can be generated and used at low cost. It can be used as an identification code by marking it on small products such as semiconductors and components that cannot be displayed by barcode. Also, unlike One-dimensional barcode, Two-dimensional barcode can identify the information by the barcode itself. In addition to texts such as letters and numbers, barcode can be stored in various forms such as graphics, photographs, voice, fingerprints, and signatures. Two-dimensional barcode are divided into stacked type codes and matrix type codes, depending on how the data is organized (S. W. Kim, 2007).

Figure 2 Stacked Barcode and Matrix Barcode (S. W. Kim, 2007)

2.3 Auto Barcode Attachment System

In order to operate logistics and inventory management information based on digital software in a manufacturing plant, it is necessary to use a bar code or a medium that can exchange information with software. Various studies and attempts are being made to apply this efficiently without increasing the manufacturing cost. By printing a barcode, the label can be attached freely according to the position and shape of the attachment, according to the method, capability and setting of the assembly line, or depending on the material of the label to be attached. It is not easy to attach with little force. Barcode automatic printing system is expected to solve the problem that the assembly line in the product production process is significantly reduced, the production volume is lowered, the production fixed costs due to labor costs increase. In addition, it is expected to play a major role in increasing the added value of products and enhancing the technological competitiveness by providing a function to manage the manufacturing process while constructing a barcode attachment system (H. S. Kwoon, J. R. Park, S. H. Lee, J. T. Jung, 2004).

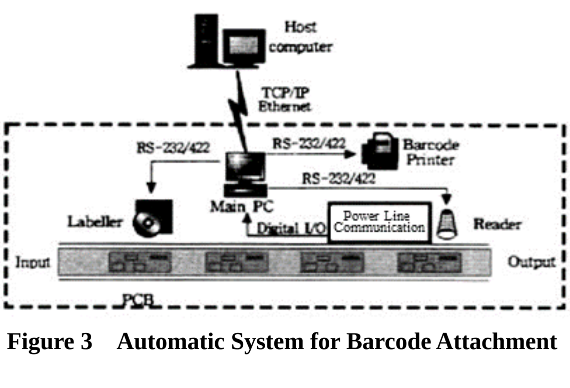

Figure 3 Automatic System for Barcode Attachment

3. Economic Analysis

Korea’s pump market forms a total of 1 trillion to 1.2 trillion, and it accounts for 50% of the total market share of three pump manufacturing companies including W. As the size of the market grows, each company is actively pursuing a system for logistics management in order to secure cost competitiveness, and QR code are considered a necessary medium to operate the system.

As a result, we have made a lot of efforts to apply the logistics system and QR code without cost increase by benchmarking the automotive parts industry and distribution industry with advanced logistics system.

In this paper, we compare and analyze the economics of the In-store Marking and Source Marking for applying QR code to the package of the finished pump.

3.1 Object for Analysis

3.1.1 In-store Marking

The worker prints the QR code on the production line and attaches it directly to the finished product box. The flow of the process checks the Part Number information in the work order provided by the production manager, and the operator inputs the information directly into the printing program installed on the site PC and outputs as much as the production quantity. It is form to ask directly.

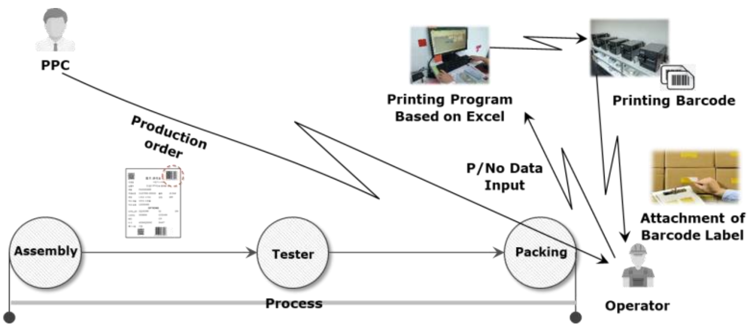

Figure 4 System Flow of In-store Marking

3.1.2 Source Marking

By applying the automatic QR code printing method based on HP TIJ2.5 technology, the field operator scans the QR code of the work order provided from the production manager and sends the print information of the product to the print controller. The QR code is printed through the installed print head as soon as the information is set and the finished product box passes through the packing facility.

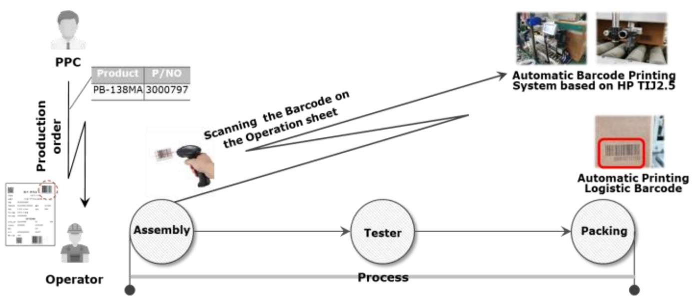

Figure 5 System Flow of Source Marking

3.2 Related Cost

The total cost is the fixed cost of QR code printing system, the initial investment cost, and the variable cost includes material cost, labor cost, and process cost (S. H. Park, S. H. Jang, M. Subramaniyam, S. I. Choi, J. Y. Song, C. W. Lee, 2008). The cost of materials proportional to the output is the cost of raw materials (toner) per unit of product, the labor cost is calculated by multiplying the hourly wage by the labor hour, and the process cost is the annual electric charge incurred in operating the facility. In this study, the influence of the factor is negligible and therefore excluded from the cost calculation.

3.2.1 Initial Investment and Additional Facility Cost

Table 1 Initial Cost of Machine

Price	In-store Marking	Source Marking
Machine	2070	4000
Additional Device	90	527

3.2.2 Material Cost

The material cost of In-house Marking is 500 KRW/EA, which is the cost of label paper and ribbon, and the material cost of Source Marketing is 582,907 KRW/EA, which is the cost of ink toner, and replacement is carried out on a 300,000EA/year or one-year basis.

3.2.3 Labor Cost

In the case of In-store marking method, the labor cost with QR code should be calculated for the labor cost, which is a direct labor cost proportional to the output, Calculations are made using increased cycle time (2.5 min/EA) due to QR code attachment and hourly pay. In the case of the source marking method, the maintenance labor cost of the QR code printing system should be calculated.

It is using W company’s maintenance work standard 2 times/week, 1 hour/day and hourly pay.

Direct and maintenance labor costs are based on W company’s wages for 2019 (44,278 KRW/hour).

3.3 Related Cost

In order to calculate the labor cost for In-store Marking, we need to predicts the production quantity for next five years from January of 2020 to December of 2024, which is the duration for economic analysis.

Since we anticipated the key factor influencing pump production quantity is the precipitation, we examined data on precipitation and production over the past three years. Table 2 shows precipitation and production quantity for rainy season over 200 mm. And Table 3 shows them for the period of normal season below 200 mm.

3.3.1 Relationship between Precipitation and Production Quantity

The following Tablel 2, Table 3 shows precipitation and pump production quantity over the last three years.

The result of the “two-sample t-test” to determine whether precipitation affects pump output using Tables 2 and 3 is shown in the following Figure 6, it is found that precipitation affects the average output of the pump.

Table 2 Precipitation and Production Quantity for Rainy Season

When	Precipitation (mm)	Production (EA)
2016, Jul	302.6	4755
2016.Sept	201.7	4573
2017.Jul	308	8565
2017.Aug	241	5900
2018.Aug	282.1	7646

Table 3 Precipitation and Production Quantity for Normal Season

When	Precipitation (mm)	Production (EA)
2016.Jun	67.4	2399
2016.Aug	76.2	3440
2016.Oct	145.3	3609
2016.Nov	34.6	2530
2016.Dec	63.1	1990
2017.Jan	15.3	3680
2017.Feb	29.8	3610
2017.Mar	24.1	3171
2017.Apr	65.0	2430
2017.May	29.5	4339
2017.Jun	60.7	3663
2017.Sept	92.1	3657
2017.Oct	67.6	3215
2017.Nov	12.7	2940
2017.Dec	22.0	2170
2018.Jan	21.1	1873
2018.Feb	32.5	2854
2018.Mar	110.7	3328
2018.Apr	133.6	3560
2018.May	123.7	2849
2018.Jun	132.1	4669
2018.Jul	172.3	6478
2018.Sept	136.5	3521
2018.Oct	164.2	5234
2018.Nov	50.5	2340
2018.Dec	27.6	2248
2019.Jan	8.1	1990
2019.Feb	30.8	2011
2019.Mar	38.7	2540
2019.Apr	79.3	3251
2019.May	55.9	2178

Regression Analysis: Production versus Precipitation

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The regression equation is
Production = 2098 + 15.5 Precipitation

Predictor       Coef    SE Coef       T      P
Constant      2098.1      226.4    9.27  0.000
Precipit      15.520      1.783    8.71  0.000

S = 888.2      R-Sq = 69.0%     R-Sq(adj) = 68.1%

Analysis of Variance

Source          DF        SS        MS       F      P
Regression       1  59794393  59794393   75.80  0.000
Residual Error  34  26820459    788837
Total           35  86614852
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Figure 6 Population mean difference test for precipitation

3.3.2 Regression Analysis

Using the Minitab statistical software, the correlation between precipitation and production is analyzed and a regression equation is obtained based on the data in Tables 2 and 3.

Correlations: Precipitation, Production

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Pearson correlation of Precipitation and Production = 0.831
P-Value = 0.000
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Figure 7 Correlation and Regression Analysis

As a result of the correlation analysis between the precipitation and production, as shown in Figure 7, there is a linear correlation between the two variables. And we can the following equation (1) to predict the production quantity from the regression result.

$$\text{Production} = 2098 + 15.5\ \text{Precipitation} \quad (1)$$

3.3.3 RCP Scenario

In the last 100 years (1912 ~ 2010), due to the effects of global warming and urbanization, Korea has risen at a rate of 0.18°C/10 years, and during the same period, the rainfall has increased rapidly at a rate of 21 mm/10 years. Based on the assessment of the impacts and vulnerabilities of climate change, domestic research for adaptation to climate change is being activated, and the demand for climate change scenarios has increased. The Meteorological Administration has developed and provided global and Korean climate change scenarios up to 2100 in the future, in accordance with the Special Report on Emission Scenarios (SRES) (IPCC, 2001) used in the IPCC Climate Change Assessment Report (IPCC, 2007). Following the publication of the 4th IPCC Climate Change Assessment Report in 2007, the international community newly selected the standard greenhouse gas scenario as the Representative Concentration Pathway (RCP) for the preparation of the 5th IPCC Climate Change Report, which is scheduled for 2013-2014. We published a climate change scenario based on the RCP, which is the same as Table 4. The National Meteorological Institute, in cooperation with the Hadley Center of the UK Meteorological Administration, began the development of global climate change scenarios by introducing the Earth System Model since 2009 (S. J. Kong, J. S. Kim, K. C. Yang, K. J. Kim, 2015). RCP scenario is characterized by calculating socio-economic assumptions based on future social structure in consideration of GHG changes according to whether climate change response policy is implemented in the process of calculating GHG concentration. 2020 uses grid-based scenarios (12.5 km resolution, HadGEM3-RA), and 2021 through 2024 administrative district-based scenarios.

3.3.4 Estimation of Production Quantity

Utilizing the information of the regression analysis and RCP precipitation data, we can estimate the production quantity for future 5 years, as shown in Table 6.

Table 4 Characteristics by RCP Version

RCP version	Characteristics
RCP 2.6	When the Earth itself can recover the effects of human activities
RCP 4.5	When greenhouse gas reduction policy is realized considerably
RCP 6.0	When greenhouse gas reduction policy is realized to some extent
RCP 8.5	GHG emissions due to current trends (without reduction)

Table 5 Future Precipitation of RCP Data (Unit : mm)

Year	2020	2021	2022	2023	2024
Jan	21.70	19.87	23.31	20.93	32.8
Feb	20.98	37.34	24.05	24.43	17.09
Mar	94.82	13.85	55.11	73.66	38.84
Apr	101.34	72.55	104.53	33.48	94.18
May	118.23	156.31	41.25	149.92	48.09
Jun	203.51	130.29	192.89	159.52	201.31
Jul	163.92	451.58	413.52	277.37	313.31
Aug	85.33	381.32	258.92	189.57	172.16
Sep	51.34	126.42	111.71	140.74	135.56
Oct	76.34	40.88	92.17	82.98	30.91
Nov	64.01	30.34	37.98	12.66	1.79
Dec	59.20	20.05	25.92	39.59	37.22

Table 6 Future Production Quantity by Month (unit : EA)

Year	2020	2021	2022	2023	2024
Jan	2434	2406	2459	2422	2606
Feb	2423	2677	2471	2477	2363
Mar	3568	2313	2952	3240	2700
Apr	3669	3223	3718	2617	3558
May	3931	4521	2737	4422	2843
Jun	5252	4117	5088	4571	5218
Jul	4639	9097	8508	6397	6954
Aug	3421	8008	6111	5036	4766
Sep	2894	4058	3830	4279	4199
Oct	3281	2732	3527	3384	2577
Nov	3090	2568	2687	2294	2126
Dec	3016	2409	2500	2712	2675

3.4 Total Cost

The QR code attaching labor cost for In-store Marking is calculated by multiplication of standard working hours for the product and the estimated production quantity and hourly wage of attaching worker.

The sum of initial investment cost, additional facility cost, material cost, maintenance labor cost, and attaching labor cost for In-store Marking is summarized in Table 7. Table 8 shows them for Source Marking.

Table 7 Cost for In-store marking (unit : 100000 KRW)

When	Initial investment	FW (In-Store)		
2020 Jun.	2,160	2,631		
When	**Material**	**Labor**	**Material+Labor**	**FW (In-Store)**
2020 Jun.	12	45	57	70
2020 Feb.	12	45	57	69
2020 Mar.	18	66	84	102
2020 Apr.	18	68	86	105

2020 May	20	73	92	112
2020 Jun.	26	97	123	150
2020 Jul.	23	86	109	132
2020 Aug.	17	63	80	98
2020 Sep.	14	53	68	83
2020 Oct.	16	61	77	94
2020 Nov.	15	57	72	88
2020 Dec.	15	56	71	86
2021 Jun.	12	44	56	69
2021 Feb.	13	49	63	76
2021 Mar.	12	43	54	66
2021 Apr.	16	59	76	92
2021 May	23	83	106	129
2021 Jun.	21	76	97	118
2021 Jul.	45	168	213	260
2021 Aug.	40	148	188	229
2021 Sep.	20	75	95	116
2021 Oct.	14	50	64	78
2021 Nov.	13	47	60	73
2021 Dec.	12	44	56	69
2022 Jun.	12	45	58	70
2022 Feb.	12	46	58	71
2022 Mar.	15	54	69	84
2022 Apr.	19	69	87	106
2022 May	14	51	64	78
2022 Jun.	25	94	119	145
2022 Jul.	43	157	200	243
2022 Aug.	31	113	143	175
2022 Sep.	19	71	90	109
2022 Oct.	18	65	83	101
2022 Nov.	13	50	63	77
2022 Dec.	12	46	59	71
2023 Jun.	12	45	57	69
2023 Feb.	12	46	58	71
2023 Mar.	16	60	76	93
2023 Apr.	13	48	61	75
2023 May	22	82	104	126
2023 Jun.	23	84	107	131
2023 Jul.	32	118	150	183
2023 Aug.	25	93	118	144
2023 Sep.	21	79	100	122
2023 Oct.	17	62	79	97
2023 Nov.	11	42	54	66

2023 Dec.	14	50	64	77
2024 Jun.	13	48	61	74
2024 Feb.	12	44	55	67
2024 Mar.	14	50	63	77
2024 Apr.	18	66	83	102
2024 May	14	52	67	81
2024 Jun.	26	96	122	149
2024 Jul.	35	128	163	199
2024 Aug.	24	88	112	136
2024 Sep.	21	77	98	120
2024 Oct.	13	48	60	74
2024 Nov.	11	39	50	61
2024 Dec.	13	49	63	76

Table 8 Cost for Source Marking (unit: 100000 KRW)

When	**Initial investment**	**FW (Source)**
2020.Jun	4,527	5,514
When	**Material**	**FW (Source)**
2020.Jun ~ 2024.Dec	291	354
When	**Labor**	**FW (Source)**
2020.Jun ~ 2024.Dec	638	777

There are formal and atypical techniques to analyze the economic feasibility considering investment time. Generally, the cash flow approach is widely used. Cash flows begin with the idea that money has a Time Value, which means that the value of a certain amount of money is affected not only by the amount of money, but also by the time it is received or spent. Present worth (PW), Future worth (FW), and Annual worth (AW) are, as their name implies, measures of economic value. For example, if you decide to use present value analysis to compare alternatives, it means using a single amount, expressed as the amount of money at the beginning of the planning period, which is referred to as the present. And it is the key valuation criterion that maximizes present value, provided there are no external factors of money to consider. On the other hand, if you decide to use future value analysis, you can use a single amount, expressed as the amount of money at the end of the planning period, which is referred to as the future, as a basis for comparison. Analyze the cash flows by applying the analysis and convert all the costs and benefits of the analysis to a single amount at the end of the planning period.

When the future value method is applied, the future value is expressed as the following Equation (2), where is the initial investment cost at time (month) t of the jth alternative such as In-Store and Source marking. MARR (Minimum Average Rate of Return) represents the interest rate in this study. Based on Equation (2), the future value of each target to be evaluated is calculated using an Excel spreadsheet, and the future value of the total input cost of in-store marking is 899,334,020 KRW and the future value of source marking is 664,399,757 KRW

$$FW_j = \sum_{t=0}^{n} P_{jt}(1 + MARR)^{n-t} \tag{2}$$

4. Conclusion

In this study, QR code was attached for inventory and traceability management of pumps, which are multi-products, and the economics of in-store marking and source marking were compared and analyzed. For economic analysis, the future value conversion method was applied, the economic evaluation period was applied for five years, and the interest rate for commercial borrowings was applied. The five-year output was predicted to estimate labor costs, and the output was estimated based on the regression analysis using the future precipitation based on the RCP4.5 scenario. As a result of economic analysis, it was found that the source marking method that outputs QR code on the wrapping paper in the final process of the production line is more economical. Further research will require analysis of the change in total cost of each option according to the interest rate and wage rate change in terms of sensitivity analysis.

References

Jang E. K. (2012). “A study on the RFID-application effects of inventory management”, Consulting Division, Graduate School of Consulting, Pai Chai University.

Lee Y. H. (2014). “An implementation of QR code system for logistics management”, Department of Mobile Contents, Graduate School of Information and Media Technology, Dankook University.

Ahn T. H. (2000). “Modern logistics theory”, Bang Han Publishing Co..

Lee D. Y. (2011). “A study on applications of 2-dimensional bar code system: In the cases of QR code designs”, Department of Advertising Design, The Graduate School of Industry Hongik University.

Park S. H. (2011). “A study and direction on bar code revolution — Design QR codes in Korea and overseas”, *Journal of Digital Design*, Vol. 11, No. 1, pp. 505-514.

Kim S. W. (2007). “Implementation of the embedded system based on ARM processor using the 2-dimensional bar code”, Department of Computer and Communication Engineering Graduate School, Daegu University Gyeongbuk Korea.

Kwoon H. S., Park J. R., Lee S. H. and Jung J. T. (2004). “An effective management of manufacturing information using auto barcode attachment system”, *Journal of the Korean Institute of Plant Engineering*, Vol. 9. No. 1.

Park S. H., Jang S. H., Subramaniyam M., Choi S. I., Song J. Y. and Lee C. W. (2008). “Economic analysis of micro factory for the production of micro pump using payback-period method”, Society for Computational Design and Engineering, pp. 814-818.

Kong S. J., Kim J. S., Yang K. C. and Kim K. J. (2015). “The study of adaptable plant species to the change of warmth index by using RCP4.5 and RCP8.5 scenarios in Seoul City”, *Journal of Wetlands Research*, Vol. 17, No. 3, pp. 273-282.