# Innovative Ship and Offshore Plant Design

## Part II. Offshore Plant Design

## Ch. 3 Weight Estimation of Topside Systems

Spring 2017

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# Ch. 3 Weight Estimation of Topside Systems

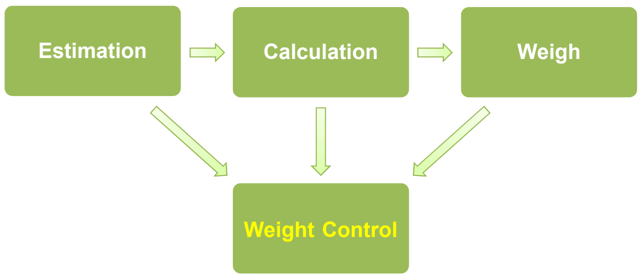
1. Generation of Weight Estimation Model by Using Statistical Method
2. Generation of Weight Estimation Model by Using Optimization Method



## Necessity of the Weight Estimation of Offshore Topsides

☑ The weight estimation of offshore topsides is necessary,
- To provide the information required for
- To estimate the to be built and the amount of to be procured
- To estimate of the project

☑ If the topsides weight can be accurately estimate at FEED state, it is possible to control efficiently the weight and to produce stably material cost.




Weight engineering process of high level

# Classification of Weight Estimation Methods (1/3)

☑ Volumetric Density Method
- A method of estimating the detailed weight group by the multiplication of space volume and bulk factor (density)
- e.g., detailed weight = space volume * bulk factor

☑ Parametrics
- A method of representing the weight with several parameters, and an essential prerequisite of the following ratiocination
- e.g., hull structural weight = $L^{1.6}(B + D)$

☑ Ratiocination
- A method of estimating the weight with a ratio from past records and a parametric equation
- e.g., hull structural weight = $C_S \cdot L^{1.6}(B + D))$

☑ Baseline Method
- A method of estimating the weight by using the result of the first one for a series of ships and offshore plants



# Classification of Weight Estimation Methods (2/3)

☑ Midship Extrapolation Method
- A method of estimating the weight by the multiplication of the length and the midship weight per unit length
- e.g., fore body weight = midship weight per unit * fore body length * coeff.

☑ Deck Area Fraction Method
- A method of estimating the weight by the multiplication of the deck area and the deck weight per unit area
- e.g., detailed weight = deck weight per area * deck area * coeff.

☑ Synthesis Method
- A method of estimating by using a delicate synthesis program which was made from the integration all engineering fields (e.g., performance) based on requirements
- Most ideal method but it needs much time and efforts.

## Classification of Weight Estimation Methods (3/3)

- ☑ **Statistical Method** ➡ To be presented here
  - A method of developing a weight equation from statistical analysis of various past records, and of estimating the weight by using the equation
- ☑ **Optimization Method** ➡ To be presented here
  - A method of developing a weight equation by optimization method such as genetic programming



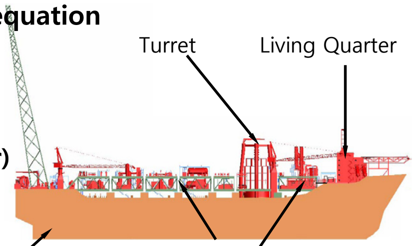
# 1. Generation of Weight Estimation Model by Using Statistical Method

## Generation of Weight Estimation Model by Statistical Method (1/11)

☑ A method of developing **a weight equation (weight estimation model) from** of various past records, and of estimating the weight by using the equation

☑ 1. Classification of FPSO weight

- FPSO weight = Hull weight (Including Living Quarter) + Topsides weight + Turret weight




☑ 2. Initial determination of individual variables

| Items | Independent Parameters |
|---|---|
| Principal dimensions | L, B, D, T, H_LWT, DWT |
| Capacity | S_C, O_P, G_P, W_P |
| Miscellaneous | Crew |

* H_LWT: Hull light weight[ton], DWT: Deadweight[ton], S_C: Storage capacity[MMbbl], O_P: Oil production[MMbopd], G_P = Gas production[MMscf/d] W_P: Water processing[MMbwpd], T_LWT: Topsides weight[ton], Crew: Crew number



## Generation of Weight Estimation Model by Statistical Method (2/11)

☑ 3. Past records of FPSOs through literature survey (Total 10 FPSOs)

| | L [m] | B [m] | D [m] | T [m] | Storage capacity [MMbbl] | Oil production [MMbopd] | Gas production [MMscf/d] | Water processing [MMbwpd] | Crew | DWT [ton] | Topside [ton] | Hull [ton] | L/Q [ton] | Total weight [ton] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Akpo | 310 | 61 | 31 | 23 | 2.00 | 0.185 | 530.00 | 0.420 | 220 | 303,669 | 37,000 | 70,500 | 2,860 | 110,360 |
| USAN | 310 | 61 | 32 | 24 | 2.00 | 0.160 | 500.00 | 0.420 | 180 | 353,200 | 27,700 | 75,750 | 3,072* | 106,522 |
| Kizomba A | 285 | 63 | 32.3 | 24 | 2.20 | 0.250 | 400.00 | 0.420 | 100 | 340,660 | 24,400 | 56,300 | 1,170 | 81,870 |
| Kizomba B | 285 | 63 | 32.3 | 25 | 2.20 | 0.250 | 400.00 | 0.420 | 100 | 340,660 | 24,400 | 56,300 | 1,170 | 81,870 |
| Greater Plutonio | 310 | 58 | 32 | 23 | 1.77 | 0.220 | 380.00 | 0.400 | 120 | 360,000 | 24,000 | 56,000 | 2,200* | 82,200 |
| Pazflor | 325 | 61 | 32 | 25 | 1.90 | 0.200 | 150.00 | 0.380 | 240 | 346,089 | 37,000 | 82,000 | 3,227 | 122,227 |
| CLOV | 305 | 61 | 32 | 24 | 1.80 | 0.160 | 650.00 | 0.380 | 240 | 350,000 | 36,300 | 63,490 | 2,900 | 102,690 |
| Agbami | 320 | 58.4 | 32 | 24 | 2.15 | 0.250 | 450.00 | 0.450 | 130 | 337,859 | 34,000 | 68,410 | 2,590 | 105,000 |
| Dalia | 300 | 60 | 32 | 23 | 2.00 | 0.240 | 440.00 | 0.405 | 160 | 416,000 | 30,000 | 52,500 | 2,500 | 85,000 |
| Skarv-Idun | 269 | 50.6 | 29 | 19 | 0.88 | 0.085 | 670.00 | 0.020 | 100 | 129,193 | 16,100 | 40,600 | 1,930* | 56,700 |

* Not defined clearly and thus estimated from the ratio of hull and L/Q weights of other FPSOs

## Generation of Weight Estimation Model by Statistical Method (3/11)

☑ 4. Determination of dependent variables through

- **Correlation**: Any of a broad class of involving dependence between variables
- Correlation analysis: One of statistical methods to analyze statistical relationships between variables
- Correlation coefficient: Degree of correlation between variables.
- The coefficient can be calculated by using Pearson method.
- According to correlation analysis, independent variables having a close connection to a dependent variable (topsides weight) can be determined.
- In this study, L, B, T, DWT, and H_LWT were selected as the revised independent variables to generate a weight equation.



## Generation of Weight Estimation Model by Statistical Method (4/11)

### Result of Correlation Analysis

| | | LBP | B | D | T | S_C | O_P | G_P | W_P | CREW | DWT | T_LWT | H_LWT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| LBP | Pearson Correlation | 1 | .365 | .513 | .676* | .464 | .298 | -.490 | .643* | .649* | .586 | .810** | .848** |
| | Sig. (2-tailed) | | .300 | .129 | .032 | .177 | .403 | .150 | .045 | .042 | .075 | .004 | .002 |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| B | Pearson Correlation | .365 | 1 | .865** | .887** | .908** | .669* | -.456 | .858** | .305 | .783** | .520 | .538 |
| | Sig. (2-tailed) | .300 | | .001 | .001 | .000 | .034 | .186 | .001 | .392 | .007 | .123 | .109 |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| D | Pearson Correlation | .513 | .865** | 1 | .924** | .894** | .803** | -.560 | .918** | .155 | .927** | .447 | .479 |
| | Sig. (2-tailed) | .129 | .001 | | .000 | .000 | .005 | .092 | .000 | .670 | .000 | .195 | .162 |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| T | Pearson Correlation | .676* | .887** | .924** | 1 | .873** | .668* | -.620 | .889** | .415 | .826** | .669* | .749* |
| | Sig. (2-tailed) | .032 | .001 | .000 | | .001 | .035 | .056 | .001 | .234 | .003 | .034 | .013 |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| S_C | Pearson Correlation | .464 | .908** | .894** | .873** | 1 | .854** | -.492 | .946** | .114 | .825** | .507 | .515 |
| | Sig. (2-tailed) | .177 | .000 | .000 | .001 | | .002 | .149 | .000 | .755 | .003 | .135 | .127 |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| O_P | Pearson Correlation | .298 | .669* | .803** | .668* | .854** | 1 | -.604 | .794** | -.225 | .747* | .251 | .164 |
| | Sig. (2-tailed) | .403 | .034 | .005 | .035 | .002 | | .065 | .006 | .533 | .013 | .484 | .651 |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| G_P | Pearson Correlation | -.490 | -.456 | -.560 | -.620 | -.492 | -.604 | 1 | -.481 | -.085 | -.498 | -.258 | -.488 |
| | Sig. (2-tailed) | .150 | .186 | .092 | .056 | .149 | .065 | | .159 | .816 | .143 | .471 | .152 |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| W_P | Pearson Correlation | .643* | .858** | .918** | .889** | .946** | .794** | -.481 | 1 | .248 | .901** | .595 | .584 |
| | Sig. (2-tailed) | .045 | .001 | .000 | .001 | .000 | .006 | .159 | | .490 | .000 | .070 | .076 |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| CREW | Pearson Correlation | .649* | .305 | .155 | .415 | .114 | -.225 | -.085 | .248 | 1 | .284 | .837** | .709* |
| | Sig. (2-tailed) | .042 | .392 | .670 | .234 | .755 | .533 | .816 | .490 | | .426 | .003 | .022 |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| DWT | Pearson Correlation | .586 | .783** | .927** | .826** | .825** | .747* | -.498 | .901** | .284 | 1 | .529 | .444 |
| | Sig. (2-tailed) | .075 | .007 | .000 | .003 | .003 | .013 | .143 | .000 | .426 | | .116 | .199 |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| T_LWT | Pearson Correlation | .810** | .520 | .447 | .669* | .507 | .251 | -.258 | .595 | .837** | .529 | 1 | .778** |
| | Sig. (2-tailed) | .004 | .123 | .195 | .034 | .135 | .484 | .471 | .070 | .003 | .116 | | .008 |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| H_LWT | Pearson Correlation | .848** | .538 | .479 | .749* | .515 | .164 | -.488 | .584 | .709* | .444 | .778** | 1 |
| | Sig. (2-tailed) | .002 | .109 | .162 | .013 | .127 | .651 | .152 | .076 | .022 | .199 | .008 | |
| | N | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |

# Generation of Weight Estimation Model by Statistical Method (5/11)

Result of Correlation Analysis

| | | L | B | T | W_P | DWT | H_LWT | T_LWT |
|---|---|---|---|---|---|---|---|---|
| L | Cor. coeff.[1] | 1.00 | 0.37 | 0.68 | 0.64 | 0.59 | 0.85 | **0.81** |
| | p-value[2] | - | 0.30 | 0.03 | 0.05 | 0.08 | 0.00 | 0.00 |
| | N[3] | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| B | Cor. coeff. | 0.37 | 1.00 | 0.89 | 0.86 | 0.78 | 0.54 | **0.52** |
| | p-value | 0.30 | - | 0.00 | 0.00 | 0.01 | 0.11 | 0.12 |
| | N | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| T | Cor. coeff. | 0.68 | 0.89 | 1.00 | 0.89 | 0.83 | 0.75 | **0.67** |
| | p-value | 0.03 | 0.00 | - | 0.00 | 0.00 | 0.01 | 0.03 |
| | N | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| DWT | Cor. coeff. | 0.59 | 0.78 | 0.83 | 0.90 | 1.00 | 0.44 | **0.53** |
| | p-value | 0.08 | 0.01 | 0.00 | 0.00 | - | 0.20 | 0.12 |
| | N | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |
| H_LWT | Cor. coeff. | 0.85 | 0.54 | 0.75 | 0.58 | 0.44 | 1.00 | **0.78** |
| | p-value | 0.00 | 0.11 | 0.01 | 0.08 | 0.20 | - | 0.01 |
| | N | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 | 10.00 |

➡ Independent variables (L, B, T, DWT, H_LWT) which have high correlation coefficients with T_LWT (to be estimated) were selected as the revised independent variables to generate a weight equation.

* 1: Correlation coefficient: Measuring the degree of correlation between two variables
* 2: p Value: Probability of obtaining a test statistic at least as extreme as the one that was actually observed, assuming that the null hypothesis is true. It has a value between 0~1. The smaller, the better.
* 3: Number of data (number of past records)



# Generation of Weight Estimation Model by Statistical Method (6/11)

☑ **5. Generation of weight equation through**

- **Regression analysis: One of statistical methods**
- **The case of one independent variable is called simple linear regression. For more than one independent variable, it is called multiple linear regression.**
- **In this study, the backward elimination method was used to generate the final regression equation.**
  - **Starting with all candidate variables, testing the deletion of each variable using a chosen model comparison criterion, deleting the variable (if any) that improves the model the most by being deleted, and repeating this process until no further improvement is possible**
  - **Through the backward elimination method, L, B, T, and DWT were selected as the final independent variables to generate a weight equation.**

## Generation of Weight Estimation Model by Statistical Method (7/11)

**Result of regression analysis**

➡ "Model 2" was selected as the final regression model by considering p value (less than 0.1).

| Model | | Beta[1] | Std. Error[2] | VIF[3] | t[4] | PV[5] | $R^2$ [6] | PV of F[7] |
|---|---|---|---|---|---|---|---|---|
| 1 | (Const.) | -192,557.8 | 138,275.4 | | -1.39 | 0.24 | 0.78 | 0.165 |
| | L | 573.6 | 372.8 | 1.42 | 1.54 | 0.20 | | |
| | B | 2,213.4 | 1,763.9 | 1.13 | 1.26 | 0.28 | | |
| | T | -2,222.3 | 3,874.6 | -0.52 | -0.57 | 0.60 | | |
| | DWT | -55.3 | 71.9 | -0.59 | -0.77 | 0.49 | | |
| | **H_LWT** | -0.2 | 0.5 | -0.39 | -0.44 | **0.68** | | |
| **2** | **(Const.)** | **-137,044.7** | **5,4129.1** | | **-2.53** | **0.05** | **0.77** | **0.074** |
| | **L** | **429.7** | **168.9** | **1.07** | **2.54** | **0.05** | | |
| | **B** | **1766.5** | **1,327.3** | **0.90** | **1.33** | **0.24** | | |
| | **T** | **-2554.6** | **3,483.1** | **-0.60** | **-0.73** | **0.50** | | |
| | **DWT** | **-29.1** | **37.7** | **-0.31** | **-0.77** | **0.48** | | |
| 3 | (Const.) | -117,509.5 | 45,270.8 | | -2.60 | 0.04 | 0.75 | 0.032 |
| | L | 334.8 | 104.2 | 0.83 | 3.21 | 0.02 | | |
| | **B** | 932.6 | 657.9 | 0.48 | 1.42 | **0.21** | | |
| | DWT | -31.0 | 36.1 | -0.33 | -0.86 | 0.42 | | |
| 4 | (Const.) | -88,217.0 | 29,166.8 | | -3.03 | 0.02 | 0.72 | 0.012 |
| | LBP | 288.4 | 87.4 | 0.72 | 3.30 | 0.01 | | |
| | B | 506.7 | 423.6 | 0.26 | 1.20 | 0.27 | | |

* 1: Regression coefficients, 2: Standard or mean error, 3: Variance Inflation Factor (Representing multicolinearity of variables. Less than 10 is good.), 4: t value, 5: p-value of each variable, 6: Adjusted $R^2$ (Representing the expectation accuracy of the regression model. To close to 1 is good.), 7: p-value of the regression model



## Generation of Weight Estimation Model by Statistical Method (8/11)

☑ **6. Generation of weight equation model for offshore plant topside**

- **The topside weight can be estimated from the following model which is comprised of L, B, T, and DWT.**

$$T_{LWT} = \beta_0 + (L)\beta_1 + (B)\beta_2 + (T)\beta_3 + (DWT)\beta_4$$

*where,*

$$\beta_0 = -137044.7$$
$$\beta_1 = 429.7$$
$$\beta_2 = 1766.5$$
$$\beta_3 = -2554.6$$
$$\beta_4 = -29.1$$

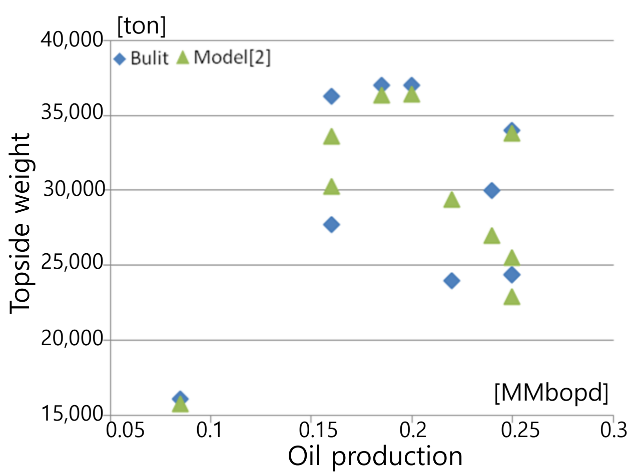
# Generation of Weight Estimation Model by Statistical Method (9/11)

☑ **7. Validation of weight estimation model**

| Past records | Actual weight [A] | Estimated weight [B] | Ratio[A/B] |
|---|---|---|---|
| Akpo | 37,000 | 36,347 | 1.020 |
| USAN | 27,700 | 33,614 | 0.820 |
| Kizomba A | 24,400 | 25,505 | 0.960 |
| Kizomba B | 24,400 | 22,951 | 1.060 |
| Greater Plutonio | 24,000 | 29,388 | 0.820 |
| Pazflor | 37,000 | 36,431 | 1.020 |
| CLOV | 36,300 | 30,275 | 1.200 |
| Agbami | 34,000 | 33,784 | 1.010 |
| Dalia | 30,000 | 26,993 | 1.110 |
| Skarv-Idun | 16,100 | 15,770 | 1.020 |
| Mean | - | - | **1.003** |
| COV (Coefficient of Variation) | - | - | **0.116** |



# Generation of Weight Estimation Model by Statistical Method (10/11)



## Generation of Weight Estimation Model by Statistical Method (11/11)

☑ Discussion

- It is very important

  . Based on experts' experience, the variables which are less impact on the weight estimation should be excluded.

- To estimate more accurate weight, it is needed

  and to discuss the standard of weight control (e.g., the inclusion of L/Q in hull or topsides weight).

- If the detailed weight information on each module from past records is available, it is possible to generate a weight estimation model for topside modules.



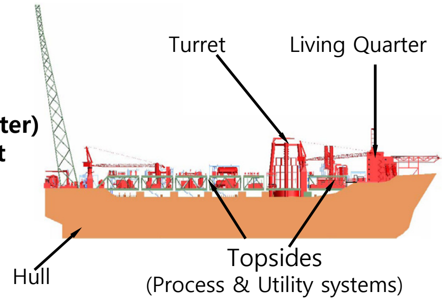
# 2. Generation of Weight Estimation Model by Using Optimization Method

## Generation of Weight Estimation Model by Optimization Method (1/7)

☑ **A method of developing** **a weight equation by** **such as genetic programming**

☑ **1. Classification of FPSO weight**

- **FPSO weight =**
  **Hull weight (Including Living Quarter)**
  **+ Topsides weight + Turret weight**




☑ **2. Initial determination of individual variables**

| Items | Independent Parameters |
|---|---|
| Principal dimensions | L, B, D, T, H_LWT, DWT |
| Capacity | S_C, O_P, G_P, W_P |
| Miscellaneous | Crew |

* H_LWT: Hull light weight[ton], DWT: Deadweight[ton], S_C: Storage capacity[MMbbl], O_P: Oil production[MMbopd], G_P = Gas production[MMscf/d] W_P: Water processing[MMbwpd], T_LWT: Topsides weight[ton], Crew: Crew number



## Generation of Weight Estimation Model by Optimization Method (2/7)

☑ **3. Past records of FPSOs through literature survey (Total 10 FPSOs)**

| | L [m] | B [m] | D [m] | T [m] | Storage capacity [MMbbl] | Oil production [MMbopd] | Gas production [MMscf/d] | Water processing [MMbwpd] | Crew | DWT [ton] | Topside [ton] | Hull [ton] | L/Q [ton] | Total weight [ton] |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Akpo | 310 | 61 | 31 | 23 | 2.00 | 0.185 | 530.00 | 0.420 | 220 | 303,669 | 37,000 | 70,500 | 2,860 | 110,360 |
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| Dalia | 300 | 60 | 32 | 23 | 2.00 | 0.240 | 440.00 | 0.405 | 160 | 416,000 | 30,000 | 52,500 | 2,500 | 85,000 |
| Skarv-Idun | 269 | 50.6 | 29 | 19 | 0.88 | 0.085 | 670.00 | 0.020 | 100 | 129,193 | 16,100 | 40,600 | 1,930* | 56,700 |

* Not defined clearly and thus estimated from the ratio of hull and L/Q weights of other FPSOs

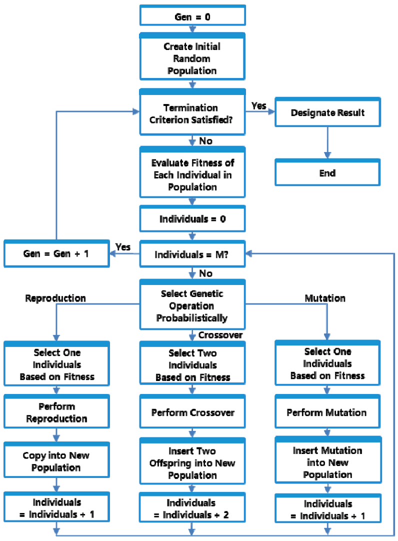
## Generation of Weight Estimation Model by Optimization Method (3/7)

☑ 4. Generation of weight equation by

- ■ Genetic Programming
  - ● One of evolutionary algorithms which evolve original solutions to better solutions
  - ● Overall procedures
    - – Step 1: Make a population with individuals which represent solutions.
    - – Step 2: Generate the next population by applying genetic operators (selection, crossover, mutation, reproduction, etc.) considering fitness to the population.
    - – Step 3: Repeat Step 2 until stopping criteria are satisfied.
- ■ Selection of terminal and function sets

set:
included in the weight equation

set: to
represent the weight equation





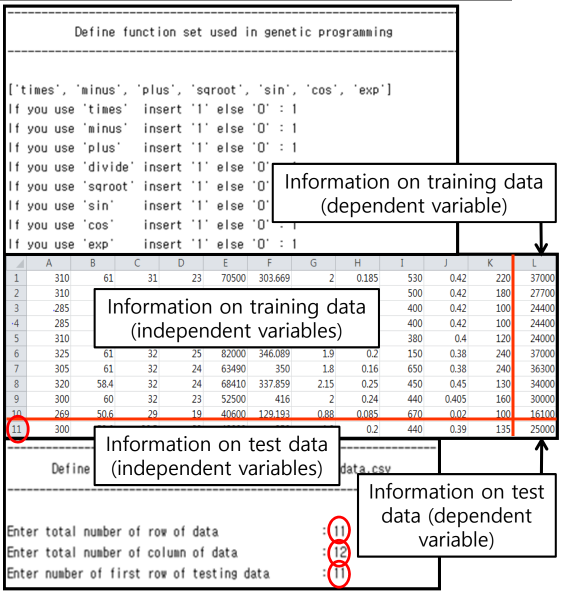

## Generation of Weight Estimation Model by Optimization Method (4/7)

**Parameters for terminal set to generate an estimation model**

| Terminal Set |
|---|
| L, B, D, T, H_LWT, DWT, S_C, O_P, G_P, W_P, Crew |

**Parameters for function set to generate an estimation model**

| Function Set |
|---|
| +, -, ×, ÷, sin, cos, exp, √ |



## Generation of Weight Estimation Model by Optimization Method (5/7)

☑ **5. Generation of weight equation model for offshore plant topside**

- **The topside weight can be estimated from the following model which is comprised of L, B, D, T, H_LWT, DWT, S_C, O_P, G_P, W_P, and Crew.**

$$T\_LWT = 67.38 \cdot Crew + 67.38 \cdot B + 67.38 \cdot S\_C - 3059 \cdot \cos(L \cdot WP \cdot (H\_LWT - 3.838)) + 12533 \cdot \cos(\exp(\sin(S\_C))) + 0.5007 \cdot B \cdot T + 67.38 \cdot O\_P \cdot G\_P + 0.5007 \cdot D \cdot \sin(H\_LWT) \cdot L^2 - 30033$$

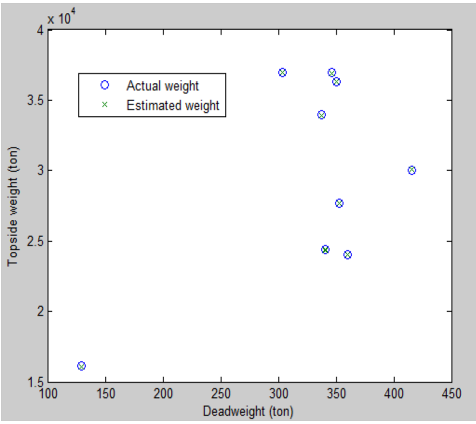


## Generation of Weight Estimation Model by Optimization Method (6/7)

☑ **6. Validation of weight estimation model**

$$T\_LWT = 67.38 \cdot Crew + 67.38 \cdot B + 67.38 \cdot S\_C - 3059 \cdot \cos(L \cdot WP \cdot (H\_LWT - 3.838)) + 12533 \cdot \cos(\exp(\sin(S\_C))) + 0.5007 \cdot B \cdot T + 67.38 \cdot O\_P \cdot G\_P + 0.5007 \cdot D \cdot \sin(H\_LWT) \cdot L^2 - 30033$$

| Past records | Actual weight [A] | Estimated weight [B] | Ratio [A/B] |
|---|---|---|---|
| Akpo | 37,000 | 36,951 | 0.9987 |
| USAN | 27,700 | 27,672 | 0.9990 |
| Kizomba A | 24,400 | 24,352 | 0.9980 |
| Kizomba B | 24,400 | 24,383 | 0.9993 |
| Greater Plutonio | 24,000 | 24,063 | 1.0226 |
| Pazflor | 37,000 | 36,918 | 0.9978 |
| CLOV | 36,300 | 36,318 | 1.0005 |
| Agbami | 34,000 | 33,906 | 0.9972 |
| Dalia | 30,000 | 30,059 | 1.0020 |
| Skarv-Idun | 16,100 | 16,093 | 0.9996 |
| Test | 25,000 | 24,928 | 0.9971 |
| Mean | | | 1.0011 |



## Generation of Weight Estimation Model by Optimization Method (7/7)

☑ Discussion

- As compared to the ,
  .
  which are included in the
  weight equation and thus
  .
  ➡ The selection process of variables which will be included in the final weight equation is needed such as correlation analysis.

- It takes much time to generate the weight equation due to the nature of evolutionary algorithms such as genetic programming.
  ➡ The time can be reduced when the number of variables (terminal set) becomes small.