Comparative Study of Conventional and Proposed Methods in Process Costing for the Refinements of Material Waste Recognition

Yuka KOIZUMI

Abstract

Although each of the SDGs demands serious attention from academia around the world, Goal 12, which states "Ensure sustainable consumption and production patterns", presents a particular challenge to those who are engaged in the Cost Accounting fields.

In this connection, the study on waste occurring during the course of a manufacturing process has been a relatively low-profile theme among the academics engaged in Cost Accounting, and arguably this reflected the view that there would not be much gained by focusing on waste.

This view, however, needs to be modified in light of the global awareness of and commitments to the SDGs as said above. This is because, if we are unable to grasp the level of waste occurring during the manufacturing process with accuracy, the enterprise in question would not be equipped with the vital information of its ongoing costs (including waste) for making appropriate managerial decisions toward achieving the SDGs.

Against this background, the writer has already questioned the validity of certain traditional assumptions made on waste and has presented an alternative method in a simplified model (Koizumi, 2021).

In this article, which is a sequel to the above, the writer elaborates the examination of the validity of the assumption commonly adopted under the conventional method, i.e., that no waste occurs from the B-WIP, and introduces a more refined method, the K-Method, in place of the conventional method.

The K-Method aims to capture the reality of the production activities with more accuracy and is based on the FIFO Method of Non-Neglect. To illustrate the differences between the conventional method and K-Method, the following two cases are examined with sample data:

Case 1: WOP (%) > The degree of completion of the E-WIP (%).

Case 2: WOP (%) ≤ The degree of completion of the E-WIP (%).

The comparison reveals that in Case 1 there are significant differences between the two methods, which are due to the presence of waste occurring from the B-WIP. On the other hand, the results are identical between the two methods in Case 2.

Key words

SDGs (Goal 12), Process Costing, Accurate Cost Measurement, Waste

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1. Introduction

In 2015 all of the United Nations Member States, including Japan, adopted the 2023 Agenda for Sustainable Development, which lists the 17 Sustainable Development Goals (SDGs), citing an urgent call for action by all countries – developed and developing – in a global partnership.

Although each of these goals demands serious attention from academia around the world, **Goal 12, "Ensure sustainable consumption and production patterns"** presents a particular challenge to those in the cost accounting field. For example, according to the Department of Economic and Social Affairs of the United Nations, as much as 13.8% of food is lost in supply chains (harvesting, transport, storage, and processing) in 2016 (United Nations, 2021b). Further, it is reported that about 10% of the global CO_2 emissions, 20% of global wastewater, 24% insecticides and 11 % of pesticides used are caused by the production of fashion products (Radhakrishnan, 2020, p65).

Goal 12 lists 11 distinct targets, which include: **Target 12.4**, "By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, following agreed international frameworks, and significantly reduce their release to air, water, and soil to minimize their adverse impacts on human health and the environment," **Target 12.5,** "By 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse," and **Target 12.6** "Encourage companies, large and transnational companies especially, to adopt sustainable practices and to integrate sustainability information into their reporting cycles."

In this connection, the study on waste occurring during the course of a manufacturing process has been a relatively minor and low-key area among the academics engaged in cost accounting, and arguably this reflected the view of the industry that there would not be much to be gained by focusing on waste which meant little value to them.

This view, however, needs to be modified in light of the global awareness of and commitments to SDGs as said above, and it is the writer's opinion that further study of waste should be encouraged in the field of cost accounting. This is because, if we are unable to grasp the level of waste occurring during the manufacturing process, the enterprise in question would not be equipped with the accurate information of its ongoing costs (including waste) and, if so, it would not be in a position to make appropriate managerial decisions toward achieving the SDGs.

Against this background, the writer questioned the validity of certain traditional assumptions made on waste and presented an alternative method in a simplified model (Koizumi, 2021).

It presented the basic concept of waste (e.g., how to calculate in terms of equivalent units), together with related formulas. This was shown by following the established practice of converting the "Process Cost Component Chart" to the "Equivalent Units Chart," and it then dealt with the Work-in-Process (WIP) Conversion Coefficient using an example of crafting a tote bag out of a sheet of leather. It highlighted that the practice in the conventional method of setting an upper limit of one (100%) to the progress completion of the Ending of WIP (E-WIP) would lead to erroneous conclusions. It finally revisited the general formula of Process Costing using the FIFO Method of Non-Neglecting Waste and offered an amended version to compute "Costs of Waste occurring from the Beginning Work-in-Process (B-WIP)," where the conventional assumption is absent.

The present article is a sequel to the above work and expands the model presented therein to accommodate more diverse situations as illustrated below.

The parameters relating to the production process are numerous, and they could produce infinite combinations of production patterns. For example, adding materials to the production process may occur at the beginning of such a production process or at the varying middle points thereof. Similarly, waste may arise at a single specific point during a one-shot or at a multiple-point production process in stages. The production line may be processing several units concurrently, with each batch being at different operational stages in the production process.

For simplicity, the present article adopts the following set of parameters, which one may also regard as notional or conceptual assumptions:

(a) the production line is processing a single batch of a particular product;
(b) 100% of the material is added at the beginning of the production process when the first operation starting the production process is about to take place;
(c) waste of such material occurs at a single point within the production process (the "WOP"), and this occurrence is normal; and
(d) the E-WIP of the previous period (therefore, the Beginning of WIP (B-WIP) of the current period) has reached a particular degree of completion as a whole.

Once the expanded model is presented by way of a mathematical formula, this will be applied to two different scenarios, so that the effect of using the expanded model will be displayed and distinguished from the traditional method tangibly and visibly.

The study method engaged is based on the theoretical framework of a general application, yet with the ability to accommodate specific requirements unique to individual cases. The analysis takes place according to a normative approach based on how product costing should describe the actual states of production activity with accuracy. The numbers ascribed to the numerical formulas and figures below are consecutive from those used in the previous article (Koizumi, 2021).

2. **Notations Used**

The followings are the explanations for the notations used in this paper.

"Q" denotes a quantity of a particular product (e.g., sheets, pieces)

$\mathrm{Q_B}$: Quantity of the B-WIP

$\mathrm{Q_G}$: Quantity of finished goods

$\mathrm{Q_w}$: Quantity of waste

(Note: theoretically unmeasurable because it is not included in a finished unit.)

$\mathrm{Q_E}$: Quantity of the E-WIP

"q" denotes the quantities of resources added to the production of a particular product (units of measurement are in metric, such as gram, meter, etc.)

$\mathrm{q_i}$: "q" relating to "Cost Component (i)"

$\mathrm{q_{Bi}}$: $\mathrm{q_i}$ contained in the B-WIP

$\mathrm{q_{Gi}}$: $\mathrm{q_i}$ in finished goods, which are completed during a period$\mathrm{q_{wi}}$: $\mathrm{q_i}$ which has become waste during a period$\mathrm{q_{Ei}}$: $\mathrm{q_i}$ contained in the E-WIP

"C" denotes costs of a particular product (in this case is in $US)

$\mathrm{C_i}$: The amount of the cost related to "Cost Component (i)"

$\mathrm{C_{Bi}}$: $\mathrm{C_i}$ of the B-WIP

$\mathrm{C_{Ii}}$: $\mathrm{C_i}$ of resources added during a period

$\mathrm{C_{Gi}}$: $\mathrm{C_i}$ of finished goods

C_{wi}: C_i of waste
C_{Ei} : C_i of the E-WIP
C_{BGi}: C_i of finished goods, the work of which commenced in the previous period and completed in the current period
C_{Bwi}: C_i of waste occurred from the B-WIP
C_{IGi}: C_i of finished goods, the work of which commenced and completed in the current period
C_{Iwi} : C_i of waste occurred from finished goods, the work of which commenced and completed in the current period

"θ" **denotes a degree of completion or production progress ratio in percentage ("Conversion Coefficient" or "CC")**
θ_i **:** CC of "Cost Component (i)"
θ_{Bi} : CC applicable to the B-WIP
θ_{Ei} : CC applicable to the E-WIP
$\hat{\theta}_{wi}$: Waste Occurring Point (or WOP)
$Q\theta_i$: Equivalent unit of "Cost Component (i)" measured in terms of the finished goods

"u" denotes total quantity (including waste) consumed per finished good
u_N : The net quantity (excluding waste) consumed per finished good
u_w : Waste quantity occurred per finished good

3. Outlines of the Conventional Method

It is noted that the leading literature tends to provide textual explanations (rather than mathematical formulas) when describing the traditional non-neglective method using FIFO. For example, Section 24(1) of the Cost Accounting Standards explains:

> The process costing of finished goods and the cost of the E-WIP shall be calculated according to the following procedures. First, the manufacturing costs for the current period and the work-in-progress cost at the beginning of the period are divided into direct material cost and conversion cost in principle, and the equivalent unit of the E-WIP is calculated for direct material costs and conversion costs. For the Equivalent unit of the E-WIP, for direct material costs, the ratio of direct material consumption included in the E-WIP to that included in the finished goods is calculated and multiplied by the Q of the E-WIP. For conversion costs, the ratio of the E-WIP to the finished good shall be calculated and multiplied by the Q of the E-WIP. (Translated by the writer)

Then, Section 24(2)2 of the Cost Accounting Standards explains:

> All cost of the B-WIP shall be included in the cost of finished goods, and the manufacturing cost for the current period shall be divided proportionally between finished goods and the E-WIP according to the ratio between "the quantity of finished goods minus the Equivalent unit of the B-WIP" and "the Equivalent unit of the E-WIP", and the total cost of finished goods and the cost of the E-WIP shall be calculated (FIFO method). (Translated by the writer)

Furthermore, Section 27 of the Cost Accounting Standards explains:

> In process costing, the cost of spoilage shall, in principle, be borne by the finished goods of the period and the E-WIP, without setting a special expense item for spoilage. The treatment of waste shall be the same as that of spoilage. (Translated by the writer)

However, since method of neglect is a simplified method, its calculation results will be inaccurate except in certain cases. In this paper, we use method of non-neglect, which first calculates the cost of waste by aggregating the cost of waste quantity, and then allocates the cost of waste to finished goods and the E-WIP.

A separate calculation of each cost by the conventionally used method of Non-Neglect of FIFO (Okamoto 2000, p278 and p295), in which the cost of finished goods is divided into the cost of finished goods started in the previous period and the cost of finished goods finished in the current period, is shown below:

Cost of products commenced in the previous period and completed in the current period:

$$C_{BGi} = C_{Bi} + \frac{C_{Ii}\, Q_B\, (1 - \theta_{Bi})}{(Q_G - Q_B\, \theta_{Bi}) + Q_w \theta_{wi} + Q_E\, \theta_{Ei}} \tag{23}$$

Cost of products commenced and completed in the current period:

$$C_{IGi} = \frac{C_{Ii}\, (Q_G - Q_B)}{(Q_G - Q_B\, \theta_{Bi}) + Q_w \theta_{wi} + Q_E\, \theta_{Ei}} \tag{24}$$

Cost of the E-WIP:

$$C_{Ei} = \frac{C_{Ii}\, Q_E\, \theta_{Ei}}{(Q_G - Q_B\, \theta_{Bi}) + Q_w \theta_{wi} + Q_E\, \theta_{Ei}} \tag{25}$$

Cost of waste:

$$C_{wi} = \frac{C_{Ii}\, Q_w \theta_{wi}}{(Q_G - Q_B\, \theta_{Bi}) + Q_w \theta_{wi} + Q_E\, \theta_{Ei}} \tag{26}$$

The cost of waste may be assigned to finished goods only (as shown in Case 1 below) or to both finished goods and the E-WIP (as shown in Case 2 below), depending on the timing of the Waste Occurrence Point (WOP) and to what degree the production has been completed per the E-WIP, as illustrated below.

Case 1: WOP (%) > The Degree of Completion of the E-WIP (%)

Cost of finished goods commenced and completed in the current period after additional allocation of waste cost is expressed as follows. (We will use "C′" (C with the apostrophe) to refer to the cost after such additional allocation.)

$$C'_{Gi} = C_{Gi} + C_{wi} \tag{27}$$

Case 2: WOP (%)≤ The Degree of Completion of the E-WIP (%)

Cost of finished goods commenced and completed in the current period after additional allocation of waste cost is expressed as follows.

$$C'_{Gi} = C_{Gi} + \frac{C_{wi}(Q_G - Q_B)}{(Q_G - Q_B) + Q_E} \tag{28}$$

Cost of the E-WIP after additional allocation of waste cost is expressed as follows.

$$C'_{Ei} = C_{Ei} + \frac{C_{wi} Q_E}{(Q_G - Q_B) + Q_E} \tag{29}$$

4. Numerical Model Study (K-Method)

In this section, a new method, the alternative to the conventional method, will be presented as general formula (the "K-Method"), which is the sequel to the formulas (21) and (22) presented in the writer's earlier paper (Koizumi 2021). Further, a new concept of measuring in equivalent units will be introduced to improve the accuracy, by using the Process Cost Component Chart and the Equivalent Units Chart. Thereafter, two numerical examples will be shown to illustrate the difference between the K-Method and the conventional method.

4.1 Assumptions

The following sets of assumptions are used in this section.

4.1.1 <u>Cost Accounting Framework</u>

1. We adopt process costing for a single production process of a single product.
2. We adopt the two-part division method to split the cost of production into the Direct Materials (i=1) and the Conversion Costs (i=2).
3. We adopt FIFO (method to distinguish the works commenced in the previous period and works commenced in the current period).
4. We adopt the normal waste without spoilage is accrued.
5. The conversion costs occur in proportion to the quantity consumed of the materials used q (finished units).

4.1.2 <u>Manufacturing Steps</u>

We will adopt, for example, crafting a tote bag out of a flat leather sheet. Such crafting may entail the following steps (see also Koizumi 2021):

1. Check the quality of the leather sheet.
2. Remove any dirt, dust, and stains, and give other treatments as required.
3. Select the applicable pre-drawn template patterns.
4. Stick the template on the leather using masking tape.
5. Punch holes at the places shown in the template.
6. Adjust the cutting tools according to the condition of the leather.
7. Cut the leather according to the patterns. (WOP)
8. Apply the leather dye to the parts of the leather.
9. Stitch the parts of the leather with thread and a needle.
10. Add buttons, straps, trademarks, and accessories.
11. Conduct a visual check of the product.
12. Place the product into a protective cover and send it to the inspection department.

In the above example, although step 5 (punching holes) produces small pieces of leather, the bulk of the leather waste occurs at step 7, which will be the WOP.

4.1.3 <u>Production Activities</u>

1. All materials are added at the beginning of the production process.
2. Waste produced at a subsequent point (WOP) in the production process.
3. From a leather sheet weighing 10 kg, a rectangle-shaped piece weighing 8 kg will be cut out, leaving a two-kg waste (this waste is assumed not to have any value).
4. The measurement unit of the finished product is sheet.
5. Two periods, Period (t-1) and Period(t), are covered with the production commencing in Period (t-1).

6. The production process will not end within the period and will be completed in the following period, and therefore WIP will exist.

4.1.4 <u>Production Quantity Data (Unit: sheet)</u>

Total of 10 sheets are added to the production process in Period (t-1). The finished goods are six bags from six sheets, the E-WIP is four sheets.

Q_I^{t-1}=10 sheets, $Q_G^{t-1}=$6 sheets, $Q_E^{t-1}=Q_B^t=$4 sheets,

Total of 12 sheets are added to the production process in Period (t). The finished goods are 11 bags from eleven sheets, the E-WIP is five sheets.

Q_I^t=12 sheets, $Q_G^t=$11 sheets , $Q_E^t=$5 sheets.

Quantity of materials consumed (i=1) per unit quantity of finished goods (including waste),
u =10 kg/sheet

The net quantity of materials consumed (i=1) per unit quantity of finished goods,u_N=8 kg/sheet
Quantity of waste accrued from materials per unit finished goods, u_w=2 kg/sheet

4.1.5 <u>Cost Data</u>

1. Unit cost of materials:
   Cost of the finished product (related to the leather) is $10,000 per 10-kg sheet.
2. Costs added in Period (t-1):
   Direct Material Costs (i=1) are $100,000. ($C_{I1}^{t-1}$=$100,000)
   Conversion Costs (i=2) are $50,000. ($C_{I2}^{t-1}$=$50,000)
3. Costs added in Period(t):
   Direct Material Costs are $120,000. ($C_{I1}^{t}$=$120,000)
   Conversion Costs (i=2) are $60,000. ($C_{I2}^{t}$=$60,000)

4.1.6 <u>Timing of WOP</u>

We will consider the following two cases:
Case 1: The B-WIP will pass the WOP in the current period.
Case 2: The B-WIP will pass the WOP in the previous period.

4.1.7 <u>Conversion Coefficient ("CC") (Production Progress Ratio)</u>

1. CC of direct materials of the B-WIP and the E-WIP

   Case 1:

   CC of the E-WIP of Period (t-1): $\theta_{E2}^{t-1}=0.3$

   CC of the E-WIP of Period(t): $\theta_{E2}^{t}=0.2$

   Case 2:

   CC of the E-WIP of Period (t-1): $\theta_{E2}^{t-1}=0.6$

   CC of the E-WIP of Period(t) : $\theta_{E2}^{t}=0.7$

   $\theta_{B1}=\theta_{E1}$ (Because they are added at the beginning of a production process)
2. WOP occurs at the middle point of the production process in Period (t-1) and Period(t):
   $\hat{\theta}_{wi}$=0.5 (50%).

4.2. K-Method with a Numerical Example (Case 1)

4.2.1. Calculation of Direct Material Costs

(1) Period (t-1)

First, the above example will be graphically displayed in the format of "Process Cost Component Chart" as shown below. (Note: in Fig.9 to Fig.24 the x-axis shows "sheet", and the y-axis and the areas shown are in "kg". Also see Fig.6 and Fig.7.)

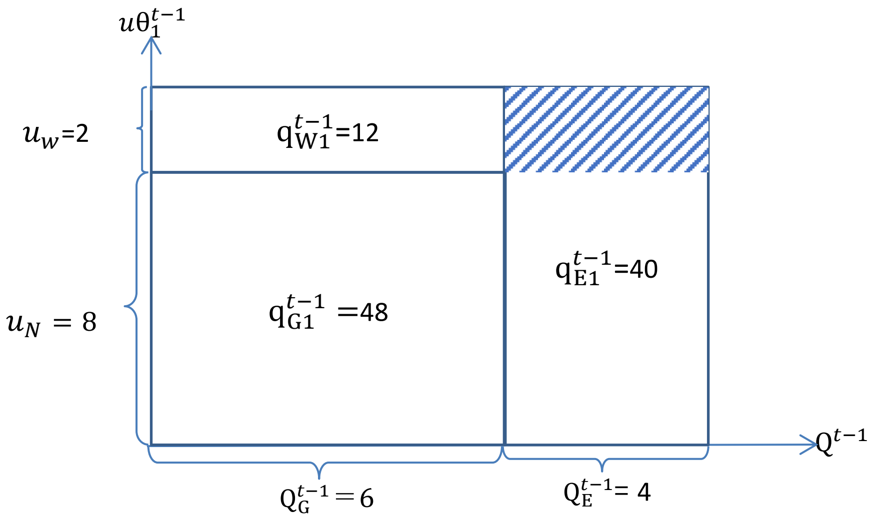

Fig.9 Process Cost Component Chart (Case 1, Period (t-1), Direct Material Costs)

In order to calculate based on equivalent units, we need to convert the "Process Cost Component Chart (Fig.9)" to the "Equivalent Units Chart (Fig.10)."

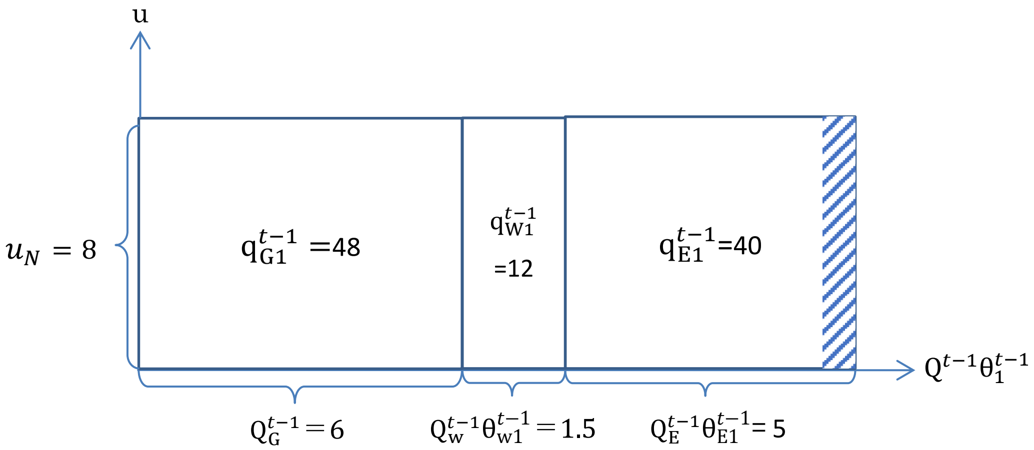

Fig.10 Equivalent Units Chart (Case 1, Period (t-1), Direct Material Costs)

The area in Fig.9 and Fig.10 represents the quantity of each direct material. Each equivalent unit ($Q\theta_i$) for each quantity in Fig.10 can be calculated by dividing each area (q_i) by the net quantity consumed per finished good (u_N). The equivalent unit of waste in Period (t-1) is given by Formula (19) as follows:

$$Q_{Iw}^{t-1}\theta_{Iw1}^{t-1} = \frac{q_{Iw1}^{t-1}}{u_N} = \frac{12}{8} = 1.5 \text{ sheets} \tag{30}$$

The cost of the E-WIP of the conventional method can be expressed by Formula (25) using the result of Formula (30) as follows:

$$C_{E1}^{t-1} = \frac{C_{I1}^{t-1}Q_E^{t-1}\theta_{E1}^{t-1}}{(Q_G^{t-1} - Q_B^{t-1}\theta_{B1}^{t-1}) + Q_{Iw}^{t-1}\theta_{Iw1}^{t-1} + Q_E^{t-1}\theta_{E1}^{t-1}} = \frac{100{,}000 \times 4 \times 1}{6 + 1.5 + 4 \times 1} = \$34{,}783 \tag{31}$$

The above Formulas are referred to within the framework of the conventional method. We now introduce the K-Method (which is marked with an asterisk).

The cost of the E-WIP in Formula (31) does not include the part that becomes waste in Period(t) (shaded area in Fig.9 and 10). Therefore, it is necessary to modify the CC of the conventional method using Formula (15). The CC of the E-WIP in Period (t-1) can be calculated as follows:

$$\theta_{E1}^{t-1} = \frac{u}{u_N} = \frac{10}{8} = 1.25 \tag{32}$$

Alternatively, the equivalent unit of the E-WIP in Period (t-1) is given as follows:

$$Q_E^{t-1}\theta_{E1}^{t-1} = \frac{q_{E1}^{t-1}}{u_N} = \frac{40}{8} = 5 \text{ sheets} \tag{33}$$

Q_E^{t-1} are four sheets, but its equivalent unit are five sheets because q_{E1}^{t-1} contains the part that will be separated as waste in the next period, since the E-WIP has not yet passed through the WOP. The cost of the E-WIP of the K-method can be expressed by Formula (25) using the result of Formulas (30) and (33) as follows:

$$C_{E1}^{t-1*} = \frac{C_{I1}^{t-1}Q_E^{t-1}\theta_{E1}^{t-1}}{(Q_G^{t-1} - Q_{BG}^{t-1}\theta_{B1}^{t-1}) + Q_{Iw}^{t-1}\theta_{Iw1}^{t-1} + Q_E^{t-1}\theta_{E1}^{t-1}} = \frac{100{,}000 \times 5}{6 + 1.5 + 5} = \$40{,}000 \tag{34}$$

Asterisk (*) indicates the method proposed by the writer (the K-method).

In order to obtain the B-WIP cost of Period(t), it is necessary to correctly calculate the E-WIP cost of Period (t-1).

(2) Period(t)

Next, we describe the method of calculating the direct material cost for Period(t).

As the calculation under the conventional method is commonly known, only the new method is presented in this subsection (2).

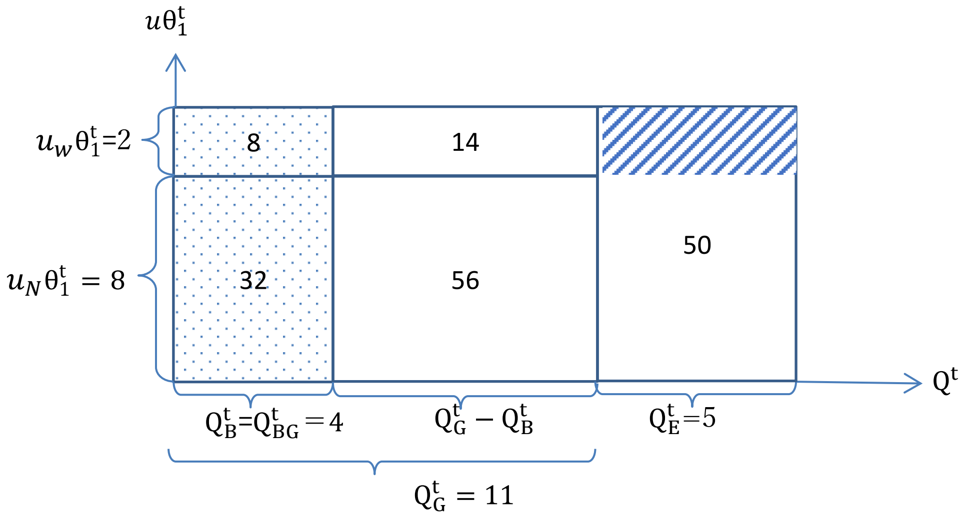

Fig.11 Process Cost Component Chart (Case 1, Period(t), Direct Material Costs)

In order to calculate based on equivalent units, we need to convert the "Process Cost Component Chart (Fig.11)" to the "Equivalent units Chart (Fig.12)". The area of Fig.11 and Fig.12 represents the quantity of each direct material.

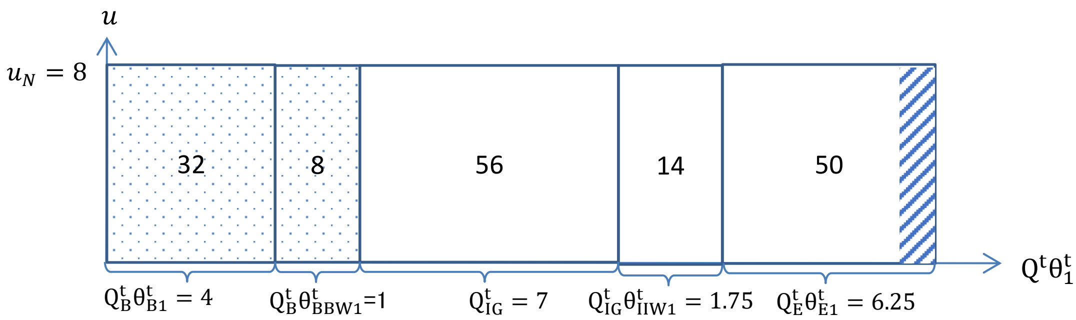

Fig.12 Equivalent Units Chart (Case 1, Period(t), Direct Material Costs)

In Fig.11 and Fig.12, the small-dotted areas and the shaded areas indicate the input quantities in Period (t-1) and the part that becomes waste in Period(t), respectively. Each equivalent unit ($Q\theta_i$) of each quantity in Fig.12 can be calculated by dividing each area (q_i) by the net quantity consumed per finished good (u_N).

Next, we show how to separate the waste portion from the B-WIP cost when this assumption is removed.

The equivalent unit of waste occurred from the B-WIP in Period(t) is given by Formula (19) as follows:

$$Q^t_B\theta^t_{BBw1} = \frac{q^t_{Bw1}}{u_N} = \frac{8}{8} = 1 \text{ sheet}$$

(35)

The cost of finished goods that were started to be produced in the previous period and completed in the current period can be expressed by Formula (21) using the result of Formula (35) as follows:

$$C^{t*}_{BG1} = \frac{C^t_{B1}Q^t_B\theta^t_{B1}}{Q^t_B\theta^t_{B1} + Q^t_B\,\theta^t_{BBw1}} = \frac{40{,}000 \times 4}{4+1} = \$32{,}000$$

(36)

The cost of waste that occurred from the B-WIP can be expressed by Formula (22) using the result of Formula (35) as follows:

$$C^{t*}_{BW1} = \frac{C^t_{B1}Q^t_B\theta^t_{Bw1}}{Q^t_B\theta^t_{B1} + Q^t_B\theta^t_{BBw1}} = \frac{40{,}000 \times 1}{4+1} = \$8{,}000$$

(37)

The equivalent unit of waste occurred from finished goods commenced and completed in the current period is given by Formula (19) as follows:

$$Q^t_{IG}\theta^t_{Iw1} = \frac{q^t_{Iw1}}{u_N} = \frac{14}{8} = 1.75 \text{ sheets}$$

(38)

The equivalent unit of the E-WIP is given by Formula (19) as follows:

$$Q^t_E\theta^t_{E1} = \frac{q^t_{E1}}{u_N} = \frac{50}{8} = 6.25 \text{ sheets}$$

(39)

Q^t_E is five sheets, but its equivalent unit is 6.25 sheets, because q^t_{E1} contains the part that will be separated as waste in the next period (the shaded area in Fig.11 and 12) since the E-WIP has not yet passed through the WOP.

The cost of finished goods commenced and completed in the current period can be expressed by Formula (24) using the result of Formulas (38) and (39) as follows:

$$C_{IG1}^{t*} = \frac{C_{I1}^{t}(Q_G^t - Q_B^t)}{(Q_G^t - Q_{BG}^t) + Q_{Iw}^t \theta_{IIw1}^t + Q_E^t \theta_{E1}^t} = \frac{120{,}000 \times (11-4)}{(11-4) + 1.75 + 6.25} = \$56{,}000$$

(40)

Similarly, the cost of the E-WIP will be C_{E1}^{t*}\$50,000 and the cost of waste that occurred from the finished goods commenced and completed in the current period will be C_{IW1}^{t*} \$14,000.

Likewise, the final cost of finished goods commenced in the previous period and completed in the current period after additional allocation of waste cost is expressed by Formula (27) using the result of Formulas (36) and (37).

$$C_{BG1}^{t*\prime} = C_{BG1}^{t*} + C_{Bw1}^{t*} = \$40{,}000$$

(41)

The final cost of finished goods commenced and completed in the current period after additional allocation of waste cost is expressed by Formula (27) as follows:

$$C_{IG1}^{t*\prime} = C_{IG1}^{t*} + C_{Iw1}^{t*} = 56{,}000 + 14{,}000 = \$70{,}000$$

(42)

4.2.2. Calculation of Conversion Costs

(1) Period (t-1):

Just like how direct material costs are calculated, the above example will be graphically displayed in the format of "Process Cost Component Chart" as shown below.

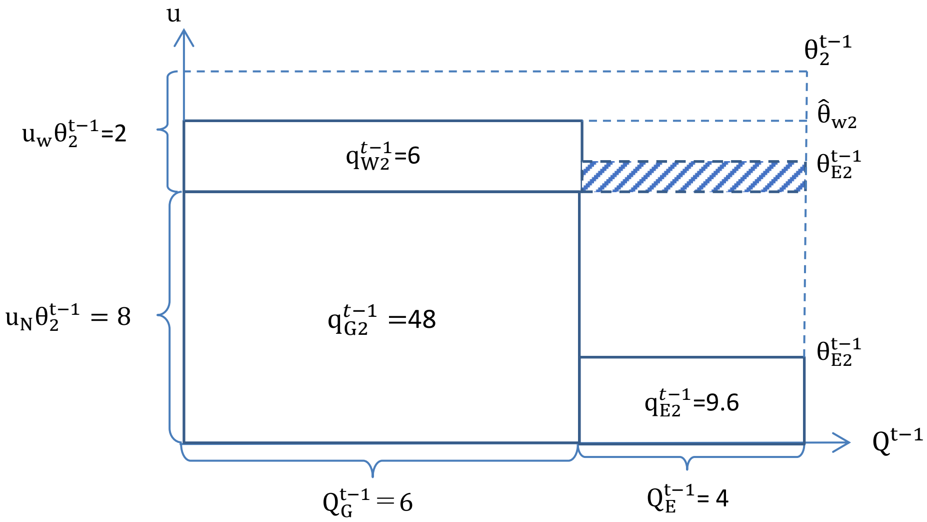

Fig.13 Process Cost Component Chart (Case 1, Period (t-1), Conversion Costs)

In Fig.13 the situation of processing including waste up to WOP is shown separately for u_N and u_w. The lower half of the rightmost y-axis (dashed line) of Fig. 13 shows the ratio of $\theta_{E2}^{t}$to u_N. The upper half of the same y-axis shows the ratio of θ_{E2}^{t} to u_w.

In order to calculate based on equivalent units, we need to convert the "Process Cost Component Chart (Fig.13)" to the "Equivalent Units Chart (Fig.14)".

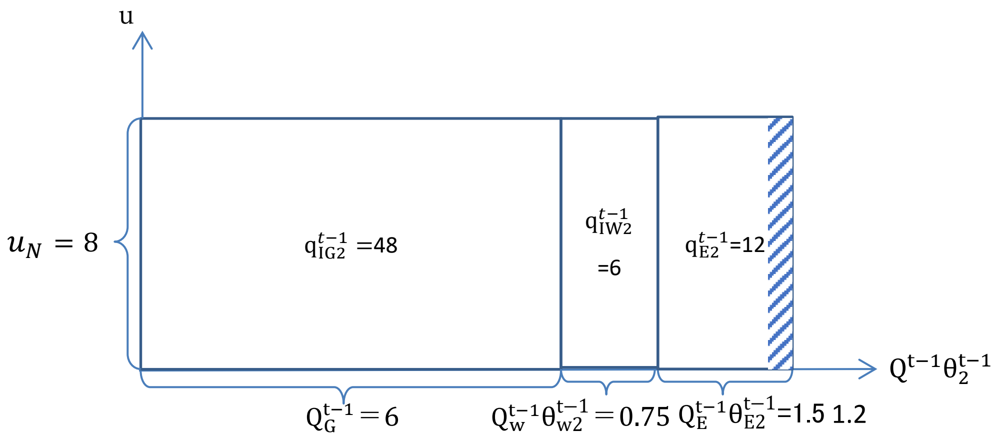

Fig.14 Equivalent Units Chart (Case 1, Period (t-1), Conversion Costs)

Each area in Fig.13 and Fig.14 shows the consumption quantity of each conversion cost input to the finished goods. In order to obtain the B-WIP cost of Period(t), it is necessary to correctly calculate the E-WIP cost of Period (t-1). Each equivalent unit ($Q\theta_i$) for each quantity in Fig. 14 can be calculated by dividing each area (q_i) by the net quantity consumed per finished good (u_N).

The equivalent unit of waste in the Period (t-1) is given by Formula (19) as follows:

$$Q_{Iw}^{t-1}\theta_{Iw2}^{t-1} = \frac{q_{Iw2}^{t-1}}{u_N} = \frac{6}{8} = 0.75 \text{ sheet} \tag{43}$$

The cost of the E-WIP of the conventional method can be expressed by Formula (25) using the result of Formula (43) as follows:

$$C_{E2}^{t-1} = \frac{C_{I2}^{t-1}Q_E^{t-1}\theta_{E2}^{t-1}}{(Q_G^{t-1} - Q_{BG}^{t-1}\theta_{B2}^{t-1}) + Q_{Iw}^{t-1}\theta_{IIw2}^{t-1} + Q_E^{t-1}\theta_{E2}^{t-1}} = \frac{50{,}000 \times 4 \times 0.3}{6 + 0.75 + 4 \times 0.3} = \$7{,}547 \tag{44}$$

The K- Method proposed by the writer is shown next.

The cost of the E-WIP in Formula (44) does not include the part that becomes waste in Period(t) (the shaded area in Fig.14). The E-WIP is processed up to the WOP, including the part that becomes waste. It consists of (q_{E2}^{t-1}) and the shaded area (the part that becomes waste in Period(t)) in Fig.14.

q_{E2}^{t-1} is modified as follows:

$$q_{E2}^{t-1*} = Q_E^{t-1}\theta_{E2}^{t-1}(u_N + u_w) = 4 \times 0.3 \times (8 + 2) = 12\text{kg} \tag{45}$$

Therefore, it is necessary to modify the equivalent unit of the conventional method using Formula (45) as follows:

$$Q_E^{t-1*}\theta_{E2}^{t-1*} = \frac{q_{E2}^{t-1*}}{u_N} = \frac{12}{8} = 1.5 \text{ sheets} \tag{46}$$

The cost of the E-WIP of the K-method can be expressed by Formula (25) using the result of Formulas (43) and (46) as follows:

$$C_{E2}^{t-1*} = \frac{C_{I2}^{t-1}Q_E^{t-1}\theta_{E2}^{t-1}}{(Q_G^{t-1} - Q_{BG}^{t-1}\theta_{B2}^{t-1}) + Q_{IG}^{t-1}\theta_{IIw2}^{t-1} + Q_E^{t-1*}\theta_{E2}^{t-1*}} = \frac{50{,}000 \times 1.5}{6 + 0.75 + 1.5} = \$9{,}090 \tag{47}$$

(2) Period(t)

Next, we describe the method of calculating the conversion cost for the Period(t). Since the solution of the conventional method is well known, only the new method is presented in this section. Just like how conversion costs of Period (t-1) are calculated, the above example will be graphically displayed in the format of "Process Cost Component Chart" as shown below:

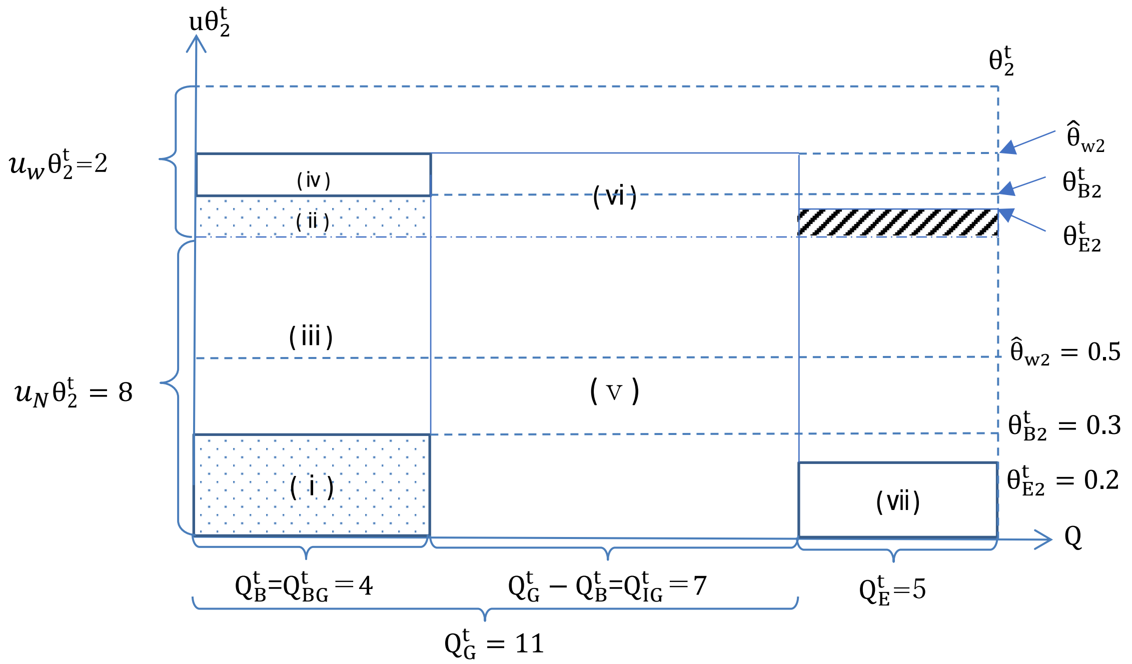

Fig.15 Process Cost Component Chart (Case 1, Period(t), Conversion Costs)

In Fig.15, the situation of processing that includes waste up to WOP is shown separately for u_N and u_w. The lower half of the rightmost y-axis (dashed line) of Fig.15 shows the ratio of θ_{B2}^t and θ_{E2}^t to u_N. The upper half of the same y-axis shows the ratio of θ_{B2}^t and θ_{E2}^t to u_w. In order to calculate based on equivalent units, we need to convert the "Process Cost Component Chart (Fig.15)" to the "Equivalent Units Diagram (Fig.16)".

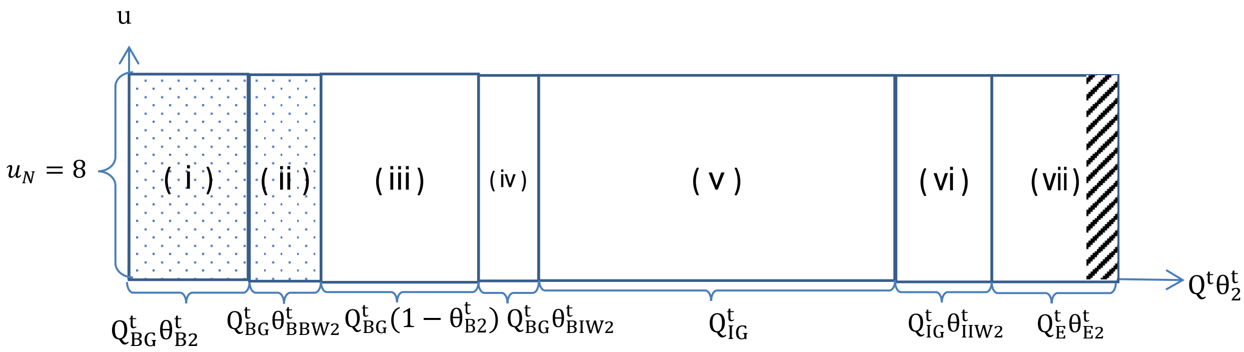

Fig.16 Equivalent Units Diagram (Case 1, Period(t), Conversion Costs)

Each area in Fig.15 and Fig.16 shows the consumption quantity of each conversion cost input to the finished goods. Each equivalent unit ($Q\theta_i$) for each quantity in Fig.16 can be calculated by dividing each area (q_i) by the net quantity consumed per finished good (u_N). In Fig. 15 and Fig. 16, the small dot pattern areas and the shaded areas indicate the input quantities in Period (t-1) and the part that becomes waste in Period (t+1), respectively.

Next, we show how to separate the waste portion from the B-WIP cost when this assumption is removed.

(i) The quantity of the finished goods commenced and generated from inputs in Period (t-1):

$$q^t_{BBG2} = Q^t_{BG}\theta^t_{B2}u^t_{N2} = 4\times0.3\times8 = 9.6 \text{ kg} \tag{48}$$

This equivalent unit is given by Formula (19) as follows:

$$Q^t_{BG}\theta^t_{B2} = \frac{q^t_{BBG2}}{u_N} = \frac{9.6}{8} = 1.2 \text{ sheets} \tag{49}$$

(ii) The waste generated from the B-WIP of Period(t) and generated from inputs in Period (t-1):

$$q^t_{BBw2} = Q^t_{BG}\theta^t_{B2}u_w = 4\times0.3\times2 = 2.4 \text{ kg} \tag{50}$$

This equivalent unit is given by Formula (19) as follows:

$$Q^t_{BG}\theta^t_{BBw2} = \frac{q^t_{BBw2}}{u_N} = \frac{2.4}{8} = 0.3 \text{ sheet} \tag{51}$$

The cost of finished goods commenced in Period (t-1) and completed in Period(t) and generated from inputs in Period (t-1) can be expressed by Formula (21) using the result of Formulas (49) and (51) as follows:

$$C^{t*}_{BG2} = \frac{C^t_{B2}Q^t_{BG}\theta^t_{B2}}{Q^t_{BG}\theta^t_{B2} + Q^t_{BG}\theta^t_{BBw2}} = \frac{9{,}090\times1.2}{1.2+0.3} = \$7{,}272 \tag{52}$$

The cost of the waste that occurred from the B-WIP of Period(t) and generated from inputs in Period (t-1) can be expressed by Formula (22) using the result of Formulas (49) and (51) as follows:

$$C^{t*}_{Bw2} = \frac{C^t_{B2}Q^t_{Bw}\theta^t_{BBw2}}{Q^t_{B}\theta^t_{B2} + Q^t_{Bw}\theta^t_{BBw2}} = \frac{9{,}090\times0.3}{1.2+0.3} = \$1{,}818 \tag{53}$$

In the same way as above, the quantity consumed (q^t_2) is calculated from Fig.15, and then the equivalent unit is calculated from Fig.16, which yields the following values.

(iii) The quantity of the finished goods commenced in Period (t-1) and generated from inputs in Period(t):

$$q^t_{BIG2} = Q^t_{BG}(1-\theta^t_{B2})u_N = 4\times(1-0.3)\times8 = 22.4 \text{ kg} \tag{54}$$

This equivalent unit is given using the result of Formula (54) as follows:

$$Q^t_{BG}(1-\theta^t_{B2}) = \frac{q^t_{BIG2}}{u_N} = \frac{22.4}{8} = 2.8 \text{ sheets} \tag{55}$$

(iv) The quantity of waste generated from the B-WIP of Period(t) and generated from inputs in Period(t):

$$q^t_{BIw2} = Q^t_{BG}(\hat{\theta}_{w2} - \theta^t_{B2})u_w = 4\times(0.5-0.3)\times2 = 1.6 \text{ kg} \tag{56}$$

This equivalent unit is given by Formula (19) using the result of Formula (55) as follows:

$$Q^t_{BG}\theta^t_{BIw2} = \frac{q^t_{BIw2}}{u_N} == \frac{1.6}{8} = 0.2\text{sheet} \tag{57}$$

(v) The quantity of the finished goods commenced and generated from inputs in Period(t):

$$q^t_{IG2} = Q^t_{IG}u^t_{N2} = (Q^t_G - Q^t_{BG})u_N = (11-4)\times8 \text{ kg} = 56 \text{ kg} \tag{58}$$

This equivalent unit is given by Formula (19) using the result of Formula (58) as follows:

$$Q_{IG}^{t}=\frac{q_{IG2}^{t}}{u_N}=\frac{56}{8}=7\text{ sheets}$$

(59)

(vi) The quantity of waste generated from the finished goods of Period(t):

$$q_{IIw2}^{t}=Q_{IG}^{t}\hat{\theta}_{w2}u_w=(Q_G^t-Q_{BG}^t)\hat{\theta}_{w2}u_w=(11-4)\times 0.5\times 2=7\text{ kg} \quad (60)$$

This equivalent unit is given by Formula (19) using the result of Formula (60) as follows:

$$Q_{IG}^{t}\theta_{IIw2}^{t}=\frac{q_{IIw2}^{t}}{u_N}=\frac{7}{8}=0.875\text{ sheet}$$

(61)

(vii) The quantity contained in the E-WIP:

$$q_{E2}^{t}=Q_E^t\theta_{E2}^t(u_N+u_w)=5\times 0.2\times(8\text{ kg}+2\text{ kg})=10\text{ kg} \quad (62)$$

This equivalent unit is given by Formula (19) using the result of Formula (62) as follows:

$$Q_E^t\theta_{E2}^t=\frac{q_{E2}^t}{u_N}=\frac{10}{8}=1.25\text{ sheets}$$

(63)

The cost of finished goods, the work of which commenced in the previous period and completed in the current period, can be expressed by Formula (23) using the result of Formulas (49), (52),(57), (61), and (63) as follows:

$$C_{BG2}^{t**}=C_{BG2}^{t*}+\frac{C_{I2}^tQ_{BG}^t(1-\theta_{B2}^t)}{(Q_G^t-Q_{BG}^t\theta_{B2}^t)+Q_{BG}^t\theta_{BIw2}^t+Q_{IG}^t\theta_{IIw2}^t+Q_E^t\theta_{E2}^t}$$
$$=7{,}272+\frac{60{,}000\times 4(1-0.3)}{(11-1.2)+0.2+0.875+1.25}=\$21{,}127$$

(64)

Equation (64) above shows the cost of the combined portion of (i) and (iii) in Figs.15 and 16.

The cost of waste that occurred from the B-WIP can be expressed by Formulas (23) and (26) using the result of Formulas (49), (53), (57), (61), and (63) as follows:

$$C_{Bw2}^{t**}=C_{Bw2}^{t*}+\frac{C_{I2}^tQ_{BG}^t\theta_{BIw2}^t}{(Q_G^t-Q_{BG}^t\theta_{B2}^t)+Q_{BG}^t\theta_{BIw2}^t+Q_{IG}^t\theta_{IIw2}^t+Q_E^t\theta_{E2}^t}$$
$$=1{,}818+\frac{60{,}000\times 0.2}{(11-1.2)+0.2+0.875+1.25}=\$2{,}808$$

(65)

Equation (65) above shows the cost of the combined portion of (ii) and (iv) in Figs.15 and 16.

The cost of finished goods commenced and finished in the current period can be expressed by Formula (24) using the result of Formulas (49), (57), (59), (61), and (63) as follows:

$$C_{IG2}^{t*}=\frac{C_{I2}^t(Q_G^t-Q_B^t)}{(Q_G^t-Q_{BG}^t\theta_{B2}^t)+Q_{BG}^t\theta_{BIw2}^t+Q_{IG}^t\theta_{IIw2}^t+Q_E^t\theta_{E2}^t}=\frac{60{,}000\times 7}{(11-1.2)+0.2+0.875+1.25}=\$34{,}640$$

(66)

Similarly, the cost of the E-WIP (C_{E2}^{t*}) will be \$6,185 and the cost of waste that occurred from the finished goods commenced and completed in the current period will be C_{IW2}^{t*} \$4,330.

Likewise, the final cost of finished goods that were started to be produced in Period (t-1) and completed in Period(t) after the additional allocation of waste cost is expressed by Formula (27) using the result of Formulas (64) and (65) as follows:

$$C_{BG2}^{t**\prime}=C_{BG2}^{t**}+C_{Bw2}^{t**}=\$23{,}935$$

(67)

The final cost of finished goods that were started and completed in Period(t) after the additional allocation of waste cost is expressed by Formula (27) as follows:

$$C_{IG2}^{t*'} = C_{IG2}^{t*} + C_{Iw2}^{t*} = \$38{,}970$$

(68)

4.3 K-method with Numerical Models (Case 2)

As the calculation under the conventional method is commonly known, only the new method is presented in this section.

4.3.1 Calculation of Direct Material Costs

(1) Period (t-1)

First, the above example will be graphically displayed in the format of "Process Cost Component Chart" as shown below.

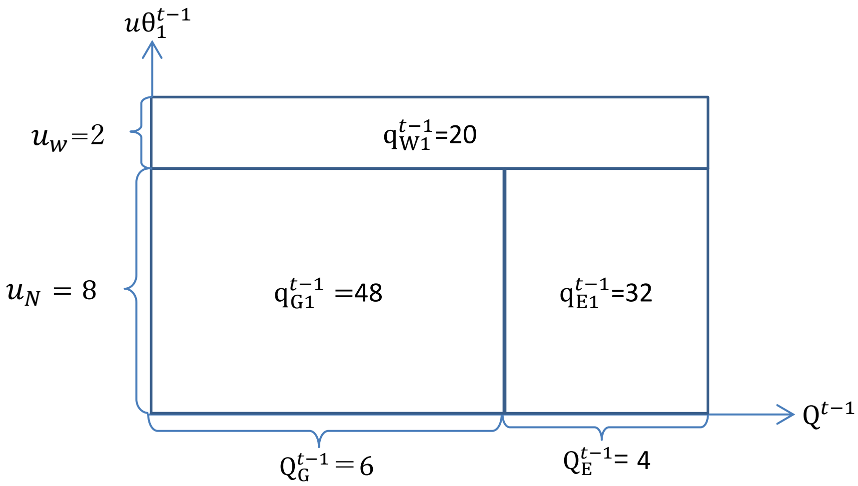

Fig.17 Process Cost Component Chart (Case 2, Period (t-1), Direct Material Costs)

In order to calculate based on equivalent units, we need to convert the "Process Cost Component Chart (Fig.17)" to the "Equivalent Units Chart (Fig.18)".

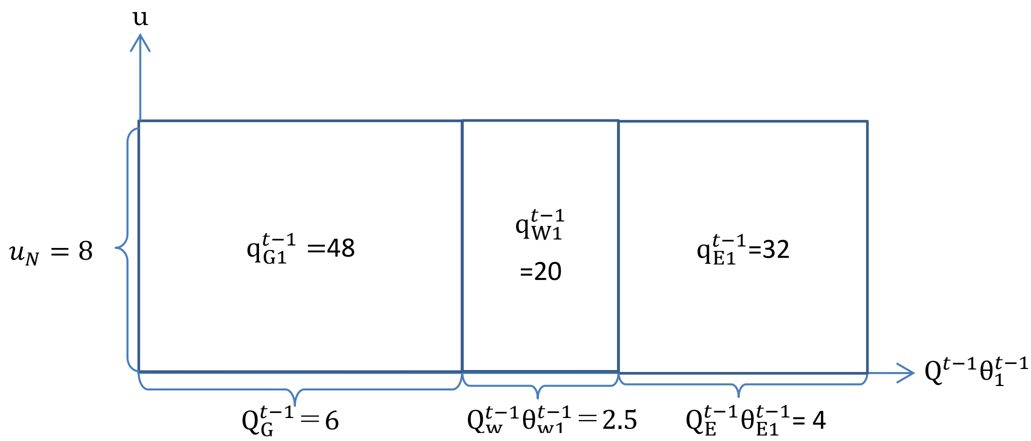

Fig.18 Equivalent Units Chart (Case 2, Period (t-1), Direct Material Costs)

The area of Fig.17 and Fig.18 represents the quantity of each direct material. Each equivalent unit ($Q\theta_i$) for each quantity in Fig.18 can be calculated by dividing each area (q_i) by the net quantity consumed per finished goods (u_N). The equivalent unit of waste in the Period (t-1) is given by Formula (19) as follows:

$$Q_{Iw}^{t-1}\theta_{Iw1}^{t-1} = \frac{q_{Iw1}^{t-1}}{u_N} = \frac{20}{8} = 2.5\text{sheets}$$

(69)

The equivalent unit of the E-WIP in Period (t-1) is given as follows:

$$Q_E^{t-1}\theta_{E1}^{t-1} = \frac{q_{E1}^{t-1}}{u_N} = \frac{32}{8} = 4\text{sheets}$$

(70)

The cost of the E-WIP of the K-method can be expressed by Formula (25) using the result of Formulas (69) and (70) as follows:

$$C_{E1}^{t-1*} = \frac{C_{I1}^{t-1}Q_E^{t-1}\theta_{E1}^{t-1}}{(Q_G^{t-1} - Q_{BG}^{t-1}\theta_{B1}^{t-1}) + Q_{IG}^{t-1}\theta_{Iw1}^{t-1} + Q_E^{t-1}\theta_{E1}^{t-1}} = \frac{100{,}000 \times 4}{6 + 2.5 + 4} = \$32{,}000$$

(71)

Similarly, the cost of finished goods commenced and completed in the current period C_{G1}^{t-1*} will be \$48,000 and the cost of waste that occurred in the current period C_{IW1}^{t-1*} will be \$20,000.

The cost of finished goods commenced and completed in the current period after the additional allocation of waste cost is expressed by Formula (28) as follows:

$$C_{G1}^{t-1*\prime} = C_{G1}^{t-1*} + \frac{C_{w1}^{t-1*}(Q_G^{t-1} - Q_B^{t-1})}{(Q_G^{t-1} - Q_B^{t-1}) + Q_E^{t-1}} = 48{,}000 + \frac{20{,}000 \times 6}{6 + 4} = \$60{,}000$$

(72)

The cost of the E-WIP after the additional allocation of waste cost is expressed by Formula (29) as follows:

$$C_{E1}^{t-1*\prime} = C_{E1}^{t-1*} + \frac{C_{w1}^{t-1*}Q_E^{t-1}}{(Q_G^{t-1} - Q_B^{t-1}) + Q_E^{t-1}} = 32{,}000 + \frac{20{,}000 \times 4}{6 + 4} = \$40{,}000$$

(73)

(2) Period (t)

Next, we describe the method of calculating the direct material cost for the Period(t).

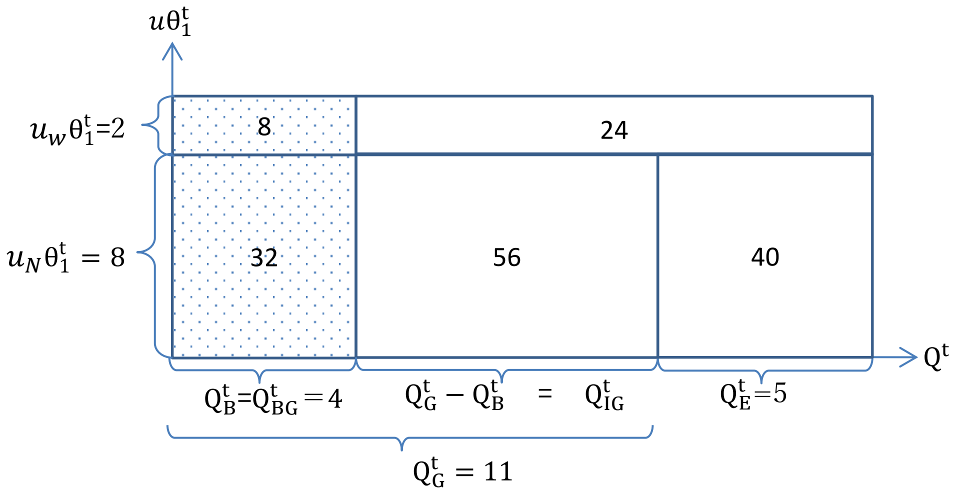

Fig.19 Process Cost Component Chart (Case 2, Period (t), Direct Material Costs)

In order to calculate based on equivalent units, we need to convert the "Process Cost Component Chart (Fig.19)" to the "Equivalent Units Chart (Fig.20)".

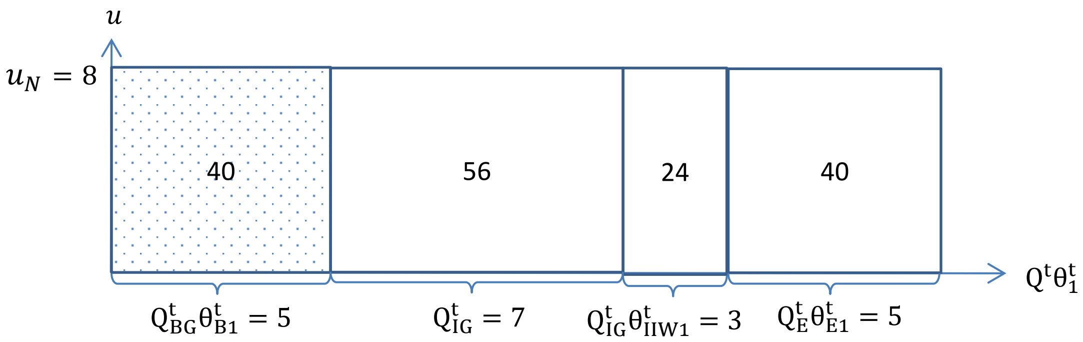

Fig.20 Equivalent Units Diagram (Case 2, Period (t), Direct Material Costs)

In Fig.19 and Fig.20, the small-dotted areas indicate the input quantities in Period (t-1). Each equivalent unit ($Q\theta_i$) in each quantity in Fig.20 can be calculated by dividing each area (q_i) by the net quantity consumed per finished good (u_N).

The equivalent unit of waste occurred from finished goods commenced and completed in Period(t) is given by Formula (19) as follows:

$$Q^t_{IG}\theta^t_{Iw1} = \frac{q^t_{Iw1}}{u_N} = \frac{24}{8} = 3 \text{ sheets} \tag{74}$$

The equivalent unit of the E-WIP is given as follows:

$$Q^t_E\theta^t_{E1} = \frac{q^t_{E1}}{u_N} = \frac{40}{8} = 5 \text{ sheets} \tag{75}$$

The cost of finished goods commenced and completed in the current period can be expressed by Formula (24) using the result of Formulas (74) and (75) as follows:

$$C^{t*}_{IG1} = \frac{C^t_{I1}(Q^t_G - Q^t_B)}{(Q^t_G - Q^t_{BG}) + Q^t_{Iw}\theta^t_{IIw1} + Q^t_E\theta^t_{E1}} = \frac{120{,}000 \times (11-4)}{(11-4)+3+5} = \$56{,}000 \tag{76}$$

Similarly, the cost of the E-WIP will be C^{t*}_{E1}\$40,000, and the cost of waste that occurred from the finished goods commenced and completed in Period(t) will be C^{t*}_{IW1}\$24,000.

The cost of finished goods commenced and completed in Period(t) after the additional allocation of waste cost is expressed by Formula (28) as follows:

$$C^{t*}_{IG1}{}' = C^{t*}_{IG1} + \frac{C^{t*}_{Iw1}(Q^t_G - Q^t_B)}{(Q^t_G - Q^t_B) + Q^t_E} = 56{,}000 + \frac{24{,}000 \times 7}{7+5} = \$70{,}000 \tag{77}$$

The cost of the E-WIP after the additional allocation of waste cost is expressed by Formula (29) as follows:

$$C^{t*}_{E1}{}' = C^{t*}_{E1} + \frac{C^{t*}_{w1}Q^t_E}{(Q^t_G - Q^t_B) + Q^t_E} = 40{,}000 + \frac{24{,}000 \times 4}{7+5} = \$50{,}000 \tag{78}$$

The cost of the E-WIP after the additional allocation of waste cost in Period (t-1) becomes cost of finished goods in Period(t). The final cost of finished goods that were started to be produced in Period (t-1) and completed in Period(t) is shown as follows:

$$C^{t-1*}_{E1}{}' = C^{t*\prime}_{BG1} = \$40{,}000 \tag{79}$$

4.3.2. Calculation of Conversion Costs

(1) Period (t-1)

Just like how conversion costs of Case 1 were calculated, the above example will be graphically displayed in the format of "Process Cost Component Chart" as shown below.

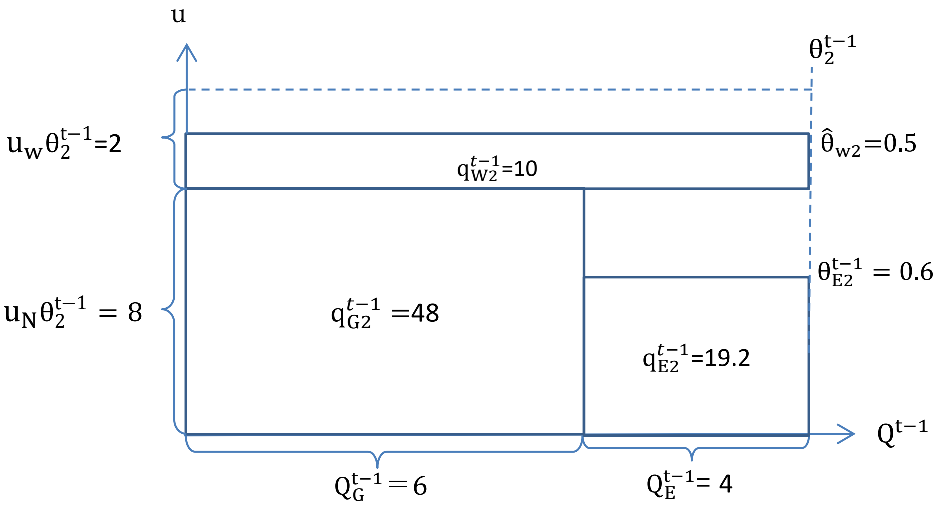

Fig.21 Process Cost Component Chart (Case 2, Period (t-1), Conversion Costs)

In Fig.21, as in Fig.13, the situation of processing, including waste up to WOP, is shown separately for u_N and u_w. The lower half of the rightmost y-axis (dashed line) of Fig.21 shows the ratio of $\theta_{E2}^{t}$to u_N. The upper half of the same y-axis shows the ratio of θ_{E2}^{t} to u_w. In order to calculate based on equivalent units, we need to convert the "Process Cost Component Chart (Fig.21)" to the "Equivalent Units Diagram (Fig.22)".

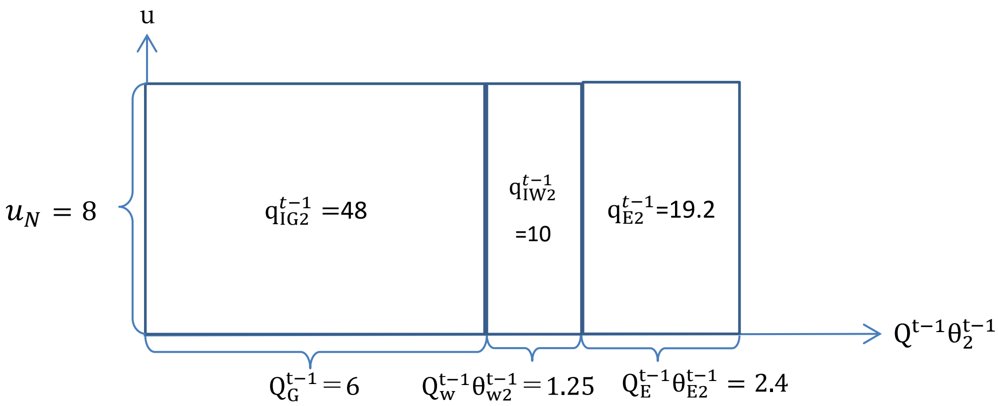

Fig.22 Equivalent Units Diagram (Case 2, Period (t-1), Conversion Costs)

Each area in Fig.21 and Fig.22 shows the consumption quantity of each conversion costs input to the finished goods. Each equivalent unit ($Q\theta_i$) for each quantity in Fig.22 can be calculated by dividing each area (q_i) by the net quantity consumed per finished good (u_N).

The equivalent unit of waste in Period (t-1) is given by Formula (19) as follows:

$$Q_{Iw}^{t-1}\theta_{Iw2}^{t-1} = \frac{q_{Iw2}^{t-1}}{u_N} = \frac{10}{8} = 1.25 \text{ sheets} \tag{80}$$

Similarly, the equivalent unit of the E-WIP in Period (t-1) is given by Formula (19) as follows:

$$Q_E^{t-1}\theta_{E2}^{t-1} = \frac{q_{E2}^{t-1}}{u_N} = \frac{19.2}{8} = 2.4\text{sheets} \tag{81}$$

The cost of the E-WIP of the K-method can be expressed by Formula (25) using the result of Formulas (80) and (81) as follows:

$$C_{E2}^{t-1^*} = \frac{C_{I2}^{t-1}Q_E^{t-1}\theta_{E2}^{t-1}}{(Q_G^{t-1} - Q_{BG}^{t-1}\theta_{B2}^{t-1}) + Q_{IG}^{t-1}\theta_{IIw2}^{t-1} + Q_E^{t-1}\theta_{E2}^{t-1}} = \frac{50{,}000 \times 2.4}{6 + 1.25 + 2.4} = \$12{,}435 \tag{82}$$

Similarly, the costs of finished goods commenced and completed in the current period (C_{G2}^{t-1*}) will be \$31,088 and the cost of waste that occurred in the current period (C_{Iw2}^{t-1*}) will be \$6,477.

The costs of finished goods that were started and completed in the current period after the additional allocation of waste cost are expressed by Formula (28) as follows:

$$C_{G2}^{t-1*\prime} = C_{G2}^{t-1*} + \frac{C_{w2}^{t-1*}(Q_G^{t-1} - Q_B^{t-1})}{(Q_G^{t-1} - Q_B^{t-1}) + Q_E^{t-1}} = 31{,}088 + \frac{6{,}477 \times 6}{6 + 4} = \$34{,}974 \tag{83}$$

The cost of the E-WIP after the additional allocation of waste cost is expressed by Formula (29) as follows:

$$C_{E2}^{t-1*\prime} = C_{E2}^{t-1*} + \frac{C_{w2}^{t-1*}Q_E^{t-1}}{(Q_G^{t-1} - Q_B^{t-1}) + Q_E^{t-1}} = 12{,}435 + \frac{6{,}477 \times 4}{6 + 4} = \$15{,}026 \tag{84}$$

(2) Period(t)

We describe the K-method of calculating the conversion cost for the Period(t). Just like how conversion costs of the Period (t-1) were calculated, the above example will be graphically displayed in the format of “Process Cost Component Chart” as shown below:

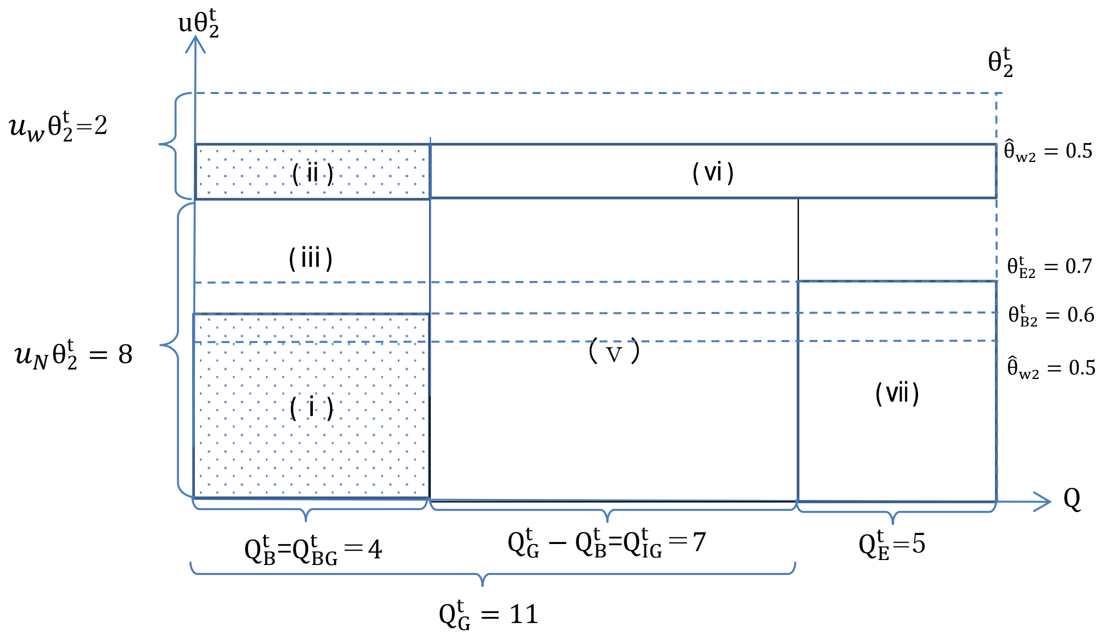

Fig.23 Process Cost Component Chart (Case 2, Period (t), Conversion Costs)

In Fig.23, the situation of processing including waste up to WOP is shown separately for u_N and u_w. The lower half of the rightmost y-axis (dashed line) of Fig.23 shows the ratio of θ_{B2}^t, θ_{E2}^t, and $\hat{\theta}_{w2}$ to u_N. The upper half of the same y-axis shows the ratio of θ_{B2}^t, θ_{E2}^t, and $\hat{\theta}_{w2}$ to u_w.

In order to calculate on the basis of equivalent units, we need to convert the "Process Cost Component Chart (Fig.23)" to the "Equivalent Units Diagram (Fig.24)".

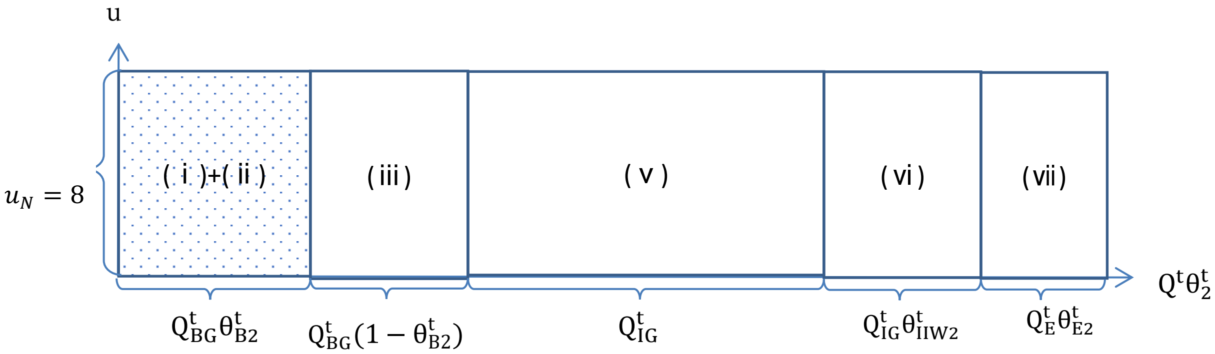

Fig.24 Equivalent Units Diagram (Case 2, Period (t), Conversion Costs)

Each area in Fig.23 and Fig.24 shows the consumption quantity of each conversion costs input to the finished goods. Each equivalent unit ($Q\theta_i$) for each quantity in Fig.24 can be calculated by dividing each area (q_i) by the net quantity consumed per a finished good (u_N).In Fig.23 and Fig.24, the small dot pattern areas indicate the input quantities in Period (t-1).

Next, we show how to separate the waste portion from the B-WIP cost when this assumption is removed.

(i) The quantity of the finished goods that were started to be produced in Period (t-1) and generated from inputs in Period (t-1):

$$q_{BBG2}^t = Q_{BG}^t\theta_{B2}^t u_{N2}^t = 4\times0.6\times8 = 19.2 \text{ kg} \quad (85)$$

This equivalent unit is given by Formula (19) as follows:

$$Q_{BG}^t\theta_{B2}^t = \frac{q_{BBG2}^t}{u_N} = \frac{19.2}{8} = 2.4 \text{ sheets} \quad (86)$$

(ii) The waste that occurred from the B-WIP of Period(t), which is the input in the Period (t-1): (Nb. Since CC of the B-WIP is after the WOP, no waste can occur from the B-WIP in Period(t)).

In the same way as above, the quantity consumed (q_2^t) is calculated from Fig.23, and then the equivalent unit is calculated from Fig.24, which yields the following values.

(iii) The quantity of the finished goods that were started to be produced in Period (t-1) and generated from inputs in Period(t):

$$q_{BIG2}^t = Q_{BG}^t(1-\theta_{B2}^t)u_N = 4\times(1-0.6)\times8 = 12.8 \text{ kg} \quad (87)$$

This equivalent unit is given by Formula (19) using the result of Formula (87) as follows:

$$Q_{BG}^t(1-\theta_{B2}^t) = \frac{q_{BIG2}^t}{u_N} = \frac{12.8}{8} = 1.6 \text{ sheets} \quad (88)$$

(iv) The quantity of waste occurred from the B-WIP of Period (t), which is the input in Period (t): (Nb. Since CC of the B-WIP is after the WOP, no waste can occur from the B-WIP in Period(t))

(v) The quantity of the finished goods that was started and generated from inputs in Period (t):

$$q_{IG2}^t = Q_{IG}^t u_{N2}^t = (Q_G^t - Q_{BG}^t)u_N = (11-4)\times8 \text{ kg} = 56 \text{ kg} \quad (89)$$

This equivalent unit is given by Formula (19) using the result of Formula (89) as follows:

$$\mathrm{Q}_{\mathrm{IG}}^{\mathrm{t}} = \frac{\mathrm{q}_{\mathrm{IG2}}^{\mathrm{t}}}{u_N} = \frac{56}{8} = 7 \text{ sheets}$$

(90)

(vi) The quantity of waste generated from the finished goods and the E-WIP in Period(t):

$$\mathrm{q}_{\mathrm{IIw2}}^{\mathrm{t}} = (\mathrm{Q}_{\mathrm{G}}^{\mathrm{t}} - \mathrm{Q}_{\mathrm{BG}}^{\mathrm{t}} + \mathrm{Q}_{\mathrm{E}}^{\mathrm{t}})\hat{\theta}_{\mathrm{w2}} u_w = (11\text{-}4\text{+}5) \times 0.5 \times 2 = 12 \text{ kg} \quad (91)$$

This equivalent unit is given by Formula (19) using the result of Formula (91) as follows:

$$\mathrm{Q}_{\mathrm{IG}}^{\mathrm{t}} \theta_{\mathrm{IIw2}}^{\mathrm{t}} = \frac{\mathrm{q}_{\mathrm{IIw2}}^{\mathrm{t}}}{u_N} = \frac{12}{8} = 1.5 \text{ sheets}$$

(92)

(vii) The quantity contained in the E-WIP:

$$\mathrm{q}_{\mathrm{E2}}^{\mathrm{t}} = \mathrm{Q}_{\mathrm{E}}^{\mathrm{t}} \theta_{\mathrm{E2}}^{\mathrm{t}} u_N = 5 \times 0.7 \times 8 \text{ kg} = 28 \text{ kg} \quad (93)$$

This equivalent unit is given by Formula (19) using the result of Formula (93) as follows:

$$\mathrm{Q}_{\mathrm{E}}^{\mathrm{t}} \theta_{\mathrm{E2}}^{\mathrm{t}} = \frac{\mathrm{q}_{\mathrm{E2}}^{\mathrm{t}}}{u_N} = \frac{28}{8} = 3.5 \text{ sheets}$$

(94)

Cost of finished goods that were started to be produced and completed in Period(t) can be expressed by Formula (24) using the result of Formulas (86), (92), and (94) as follows:

$$\mathrm{C}_{\mathrm{IG2}}^{\mathrm{t*}} = \frac{\mathrm{C}_{\mathrm{I2}}^{\mathrm{t}}(\mathrm{Q}_{\mathrm{G}}^{\mathrm{t}} - \mathrm{Q}_{\mathrm{B}}^{\mathrm{t}})}{(\mathrm{Q}_{\mathrm{G}}^{\mathrm{t}} - \mathrm{Q}_{\mathrm{BG}}^{\mathrm{t}} \theta_{\mathrm{E2}}^{\mathrm{t}}) + \mathrm{Q}_{\mathrm{Iw}}^{\mathrm{t}} \theta_{\mathrm{IIw2}}^{\mathrm{t}} + \mathrm{Q}_{\mathrm{E}}^{\mathrm{t}} \theta_{\mathrm{E2}}^{\mathrm{t}}} = \frac{60{,}000 \times 7}{(11 - 2.4) + 1.5 + 3.5} = \$30{,}882$$

(95)

Similarly, cost of the E-WIP will be $\mathrm{C}_{\mathrm{E2}}^{\mathrm{t*}}$\$15,441 and cost of waste occurred from the finished goods that were started to be produced and completed in the current period will be $\mathrm{C}_{\mathrm{IW2}}^{\mathrm{t*}}$\$6,618.

Cost of finished goods that were started to be produced and completed in the current period after the additional allocation of waste cost is expressed by Formula (28) as follows:

$$\mathrm{C}_{\mathrm{IG2}}^{t*}{}' = \mathrm{C}_{\mathrm{IG2}}^{t*} + \frac{\mathrm{C}_{\mathrm{Iw2}}^{t*}(\mathrm{Q}_{\mathrm{G}}^{t} - \mathrm{Q}_{\mathrm{B}}^{t})}{(\mathrm{Q}_{\mathrm{G}}^{t} - \mathrm{Q}_{\mathrm{B}}^{t}) + \mathrm{Q}_{\mathrm{E}}^{t}} = 30{,}882 + \frac{6{,}618 \times 7}{7 + 5} = \$34{,}742$$

(96)

Cost of the E-WIP after the additional allocation of waste cost is expressed by Formula (29) as follows:

$$\mathrm{C}_{\mathrm{E2}}^{t*}{}' = \mathrm{C}_{\mathrm{E2}}^{t*} + \frac{\mathrm{C}_{\mathrm{w2}}^{t*} \mathrm{Q}_{\mathrm{E}}^{t}}{(\mathrm{Q}_{\mathrm{G}}^{t} - \mathrm{Q}_{\mathrm{B}}^{t}) + \mathrm{Q}_{\mathrm{E}}^{t}} = 15{,}441 + \frac{6{,}618 \times 5}{7 + 5} = \$18{,}199$$

(97)

The cost of the E-WIP of the Period (t-1) (after the additional allocation of waste cost) becomes Cost of finished goods of Period(t), and as such the final Cost of Finished Goods commenced in Period (t-1) and completed in Period(t) is shown as follows:

$$\mathrm{C}_{\mathrm{BG2}}^{t*\prime} = \mathrm{C}_{\mathrm{E2}}^{t-1*\prime} = \$15{,}026$$

(98)

Cost of finished goods, the work of which commenced in the previous period and completed in the current period can be expressed by Formula (23) using the result of Formulas (86), (88), (92), (94) and (98).

$$\mathrm{C}_{\mathrm{BG2}}^{t**}{}' = \mathrm{C}_{\mathrm{BG2}}^{t*}{}' + \frac{\mathrm{C}_{\mathrm{I2}}^{\mathrm{t}} \mathrm{Q}_{\mathrm{BG}}^{\mathrm{t}}(1 - \theta_{\mathrm{B2}}^{\mathrm{t}})}{(\mathrm{Q}_{\mathrm{G}}^{\mathrm{t}} - \mathrm{Q}_{\mathrm{BG}}^{\mathrm{t}} \theta_{\mathrm{B2}}^{\mathrm{t}}) + \mathrm{Q}_{\mathrm{IG}}^{\mathrm{t}} \theta_{\mathrm{IIw2}}^{\mathrm{t}} + \mathrm{Q}_{\mathrm{E}}^{\mathrm{t}} \theta_{\mathrm{E2}}^{\mathrm{t}}}$$
$$= 15{,}026 + \frac{60{,}000 \times 1.6}{(11 - 2.4) + 1.5 + 3.5} = \$22{,}085$$

(99)

5. Comparative Analysis of Numerical Examples

The following table shows the different results from the conventional method and K-method for each of these two cases, i.e., Case 1 in which the B-WIP will pass the WOP in the current period, and Case 2 in which the B-WIP has already passed the WOP within the previous period, with other settings and assumptions being identical.

(Unit: $US)

	Conventional Method				**K-Method**			
	Direct Material		Conversion Cost		Direct Material		Conversion Cost	
	t-1	*t*	*t-1*	*t*	*t-1*	*t*	*t-1*	*t*
Case 1								
C_{BGi}	—	34,783	—	13,714 (6,167)	—	32,000	—	21,127 (13,855)
C_{Bwi}	—	—	—	—	—	8,000	—	2,808 (990)
C_{IGi}	52,174	61,091	37,736	44,197	48,000	56,000	36,365	34,640
C_{Iwi}	13,043	15,273	4,717	4,497	12,000	14,000	4,545	4,330
C_{Ei}	34,783	43,636	7,547	5,139	40,000	50,000	9,090	6,185
C'_{BGi}	—	34,783	—	13,345	—	40,000	—	23,935
C'_{IGi}	65,217	76,364	42,453	48,694	60,000	70,000	40,910	38,970
C'_{Ei}	34,783	43,636	7,547	5,139	40,000	50,000	9,090	6,185
Case 2								
C_{BGi}	—	40,000	—	22,085 (7,059)	—	40,000	—	22,085 (7,059)
C_{Bwi}	—	—	—	—	—	—	—	—
C_{IGi}	48,000	56,000	31,088	30,882	48,000	56,000	31,088	30,882
C_{Iwi}	20,000	24,000	6,477	6,618	20,000	24,000	6,477	6,618
C_{Ei}	32,000	40,000	12,435	15,441	32,000	40,000	12,435	15,441
C'_{BGi}	—	40,000	—	22,085	—	40,000	—	22,085
C'_{IGi}	60,000	70,000	34,974	34,743	60,000	70,000	34,974	34,742
C'_{Ei}	40,000	50,000	15,026	18,198	40,000	50,000	15,026	18,199

(The amounts in parentheses indicate the costs incurred in the current period.)

This table illustrates the following points:

In Case 1, under the conventional method, because the assumption made was that no waste occurs from the B-WIP, the costs of waste occurred from the B-WIP (C_{Bwi}) for Period (t) are nil for both direct material and conversion cost. On the other hand, under the K-Method, as it aims to capture the production reality, the amounts of C_{Bwi} for Period (t) are $8,000 for the direct material and $2,808 for the conversion cost (including $990 which has occurred from the works commenced in the current period), thus $10,808 in total.

Similarly, in Case 1, the conversion cost for the cost of finished goods, the work of which commenced in the previous period and completed in the current period, (C'_{BG2}) is $13,345 under the conventional method, whereas the corresponding amount is $23,935 under the K-Method, which is approximately 80% higher than under the conventional method. This highlights the point that the choice of the method could significantly affect the allocation of the conversion costs, which would provide valuable information to the management to allow more sophisticated cost management.

Although these results are based on hypothetical data, it is clear that the extent of the disparity can be significantly beyond the margin for error. This is why the writer is advocating that the conventional method needs to be refined to show the actual production scenes more accurately.

Furthermore, there are certain differences in the amounts of C'_{BGi}, C'_{IGi}, and C'_{Ei} between the conventional method and the K-Method. Whilst the degrees of the discrepancies are small, it is considered that the K-Method is capable of presenting more accurate figures.

Case 2, on the other hand, shows that both methods produce the same results.

It should be noted that in preparing the two cases, for the sake of simplicity, a number of the variables were assumed to be constant among different periods. For example, the levels of the utilization of the production line remained the same between Period (t-1), Period(t), and Period (t+1). Furthermore, the speed of the production (hence the duration of the production cycles) remained the same, and the position of the WOP remained constant in each of the production cycles. In applying the two methods, however, such assumptions may not hold in practice.

It will be beyond the scope of the present article to cover such an extended horizon, but broadly speaking, the writer is of a view that the K-Method should be preferred, where, for example, there has been a significant increase/decrease in the production volume, the duration of the production cycle has been changed, e.g. the production procedures have been accelerated to meet seasonal demands such as toys and presents at Christmas, and the position of the WOP has moved as a result of, for example, certain prior stages of the production works are rationalized by the introduction of new machinery. Academic verification thereof is yet to be explored in future research works.

6. Conclusion

In this article the validity of the assumption commonly adopted under the conventional method (i.e., that no waste occurs from the B-WIP) was questioned, and the new method, the K-Method, was introduced in place of the conventional method, which is aimed to capture the reality of the production activities with more accuracies. The K-Method is based on the FIFO Method of Non-Neglect.

The K-Method presented in this paper is the version under the following scenario regarding the production process:

(1) Materials are added to the production process at fixed points in the production process.
(2) Materials are added at the starting point of the production process.
(3) Wastes occur due to normal causes.
(4) Wastes occur at fixed points in the production process.
(5) All WIPs are located at a particular stage of the production process.

It should be noted, however, that the K-Method is not confined to the above scenario and that it is capable of covering other situations by making appropriate amendments.

In order to illustrate the differences between the conventional method and K-Method, the following two cases are examined with sample data.

Case 1: WOP (%) ＞ The degree of completion of the E-WIP (%).

Case 2: WOP (%) $\leq$ The degree of completion of the E-WIP (%).

The comparison showed that in Case 1 there were significant differences between the two methods, which were due to the presence of waste occurring from the B-WIP. On the other hand, the results were identical between the two methods in Case 2.

Let us now return to the SDGs cited at the beginning of this article, in particular Target 12.5 of SDG 12, “By 2030, substantially reduce waste generation through prevention, reduction, recycling, and reuse”. The K-Method illustrated in this article, which grasps the production process more accurately and graphically than the conventional method, directly relates to this reduction of waste generation. This is because such reduction would be possible only if one could accurately monitor the situation in which waste is generated.

In this connection, Target 12.4, which precedes Target 12.5, states that “By 2020, achieve the environmentally sound management of chemicals and all wastes throughout their life cycle, in accordance with agreed international frameworks, and significantly reduce their release to air, water, and soil to minimize their adverse impacts on human health and the environment.”

A close examination of these texts suggests to the writer that the meaning of the word "waste" is slightly different between the two. This is to say that waste in Target 12.5 refers to the inefficient use of resources, such as food loss. On the other hand, waste in Target 12.4 refers to a hazardous substance, such as carbon dioxide, which interpretation categorizes waste as chemicals. As the K-Method illustrated in this article is contemplated in the context of Target 12.5, one would therefore need to consider how the K-Method could be applied in the context of Target 12.4.

In relation to this point, it is the writer’s view that the generation and production of hazardous wastes could be dealt with in the context of byproducts, which has already been established in the cost accounting area (See the Cost Accounting Standard 28). In the traditional context, byproducts are thought to have positive values to the extent that their resale values exceed their disposal costs. Where, however, the latter exceeds the former, the negative values could be posted as an occurrence of a new category of conversion cost in the production process, and this treatment can be incorporated into the cost accounting models (including the K-Method).

On this basis, one could expand the scope of such disposal costs to cover the social environmental costs, even where such treatment might not be required by the relevant accounting standards for the preparation of the statutory accounts. This line of thought will assist in bringing Target 12.4 and Target 12.5 together and will be explored and presented by the writer’s further works.

In this connection it is noted that the industry has already been exploring a number of techniques with an aim to reduce waste in its wider meaning. For example, in the context of fashion industry two methods are used to generate zero waste in clothing manufacturing, i.e., to work and organize pattern-making based on total fabric width, and to work using remnants from other products (Gabriel & Luque, 2020, p35). Further, in terms of designing shoes, attempts have been made for soles coated with biodegradable materials, which could be detached after use, with the rest of the shoes being made of plastics and polymers that were not harmful and could be recycled into new shoes (McDonough & Braungart, 2002, p14, Gabriel & Luque, 2020, p26).

This strengthens the writer’s belief that a comprehensive model to accommodate both Target 12.4 and Target 12.5 needs to be explored, so that the manufacturers and the society will have a more sophisticated grips for achieving these Targets.

The writer notes that on August 9, 2021, the Intergovernmental Panel on Climate Change (IPCC), an organization of the United Nations, published a report titled “Climate change widespread, rapid, and intensifying”, and offered scientific evidence that human activities are causing global warming (United Nations, 2021a). This issue will continue to be discussed among the members of the global community, including the forthcoming UN Climate Change Conference (COP26) to be held in Glasgow, UK in November 2021. There is no doubt that Japan has an important role to play in these occasions.

It is submitted that the K-Method illustrated in this paper offers a step in the right direction in demonstrating what the academic accountancy community can contribute to this global issue.

Submitted: September25, 2021

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