Circular Value-added Productivity (CVP)

Hitachi–AIST Circular Economy Cooperative Research Laboratory (April 2026)

1. Introduction

The transition to a circular economy (CE) is an urgent issue for governments and industries seeking to mitigate resource depletion and ensure sustainable economic growth. To facilitate a smooth transition, there is a need for indicators that effectively reflect the performance of companies and organizations in CE activities, clearly demonstrate progress, and identify areas for improvement. Many circularity indicators capture environmental, social, and economic aspects separately; however, achieving a sustainable society requires an appropriate perspective that evaluates both environmental and economic dimensions. In recent years, integrated indicators that evaluate both dimensions simultaneously have attracted attention. Nevertheless, many existing integrated indicators emphasize economic value efficiency relative to environmental impact, such as CO_2 emissions and resource inputs, and do not sufficiently reflect elements of economic rationality that industry values, including profitability and cost structures. If companies cannot maintain profitability, the resulting challenges in sustaining CE business models will likely stall the transition to CE. Moreover, in CE business models, value creation often extends beyond the scope of a single company; value networks (VNs), in which multiple companies collaborate through the provision of products, components, and services, usually form. Therefore, when evaluating the sustainability of CE business models, it is essential to capture not only the economics of individual companies but also the economic efficiency of the network as a whole.

In this context, the Hitachi-AIST Circular Economy Cooperative Research Laboratory proposes and examines an indicator—Circular Value-added Productivity (CVP)—which evaluates the economic efficiency of CE activities using standard financial data [1–2]. This research report outlines the CVP concept, illustrates calculation methods at the single-company level based on prior studies, and discusses considerations for applying CVP to VN.

2. Circular Value-added Productivity (CVP)

2.1 Definition

This section explains the definition of CVP. CVP applies the general definition of productivity to CE business activities. The definition is as follows [1–2].

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$$CVP = \frac{Y_{\mathrm{CE}}}{E_{\mathrm{CE}}} \qquad (1)$$

Y_{CE} represents the value added from CE activities, and E_{CE} represents the expenditure on CE activities. Using standard financial data, Eq. (1) can be expressed as follows.

$$CVP = \frac{S_{\mathrm{CE}} - I_{\mathrm{CE}}}{C_{\mathrm{CE}} + G_{\mathrm{CE}}} \qquad (2)$$

S_{CE} denotes the sales from CE activities; I_{CE} denotes the intermediate goods costs for CE activities; C_{CE} denotes the cost of goods sold (COGS) for CE activities; and G_{CE} denotes the selling, general, and administrative expenses (SG&A) for CE activities. Although there are multiple definitions and calculation methods for value added, this research report adopts the commonly used subtraction method and organizes the formula using standard financial statement items. These financial items are determined depending on how the scope (boundary) of CE activities to be evaluated is defined. CVP can be flexibly applied to the evaluation of a single entity at the site level, business unit level, or company level, for example. CVP could also be applied to VNs in which multiple companies collaborate to create value or to circular systems formed within specific regions.

CVP is based on the widely accepted concept of productivity, which evaluates productivity as the ratio of value added to input resources (expenditure). This makes it easy for companies to understand and makes it highly compatible with standard financial analysis processes. Because GDP is defined as the aggregation of value added, CVP can conceptually relate firm-level activities to economic growth at the national or regional level. This characteristic allows CVP, despite its simplicity, to accurately capture the economic value creation of CE activities. CVP clarifies the relationship between value added and expenditure based on financial data, which allows for an examination of whether the additional costs associated with CE transition are reasonable and whether circular business can advance without undermining economic viability. CVP can be utilized in various situations such as current-state analysis within a company, verification of improvement measures, and year-to-year comparisons.

2.2 Calculation at the Single-Company Level

To illustrate a concrete calculation procedure for the CVP proposed in Section 2.1, this section presents a trial calculation for a waste management company operating a CE business that includes resource recovery (recycling).

For the trial calculation, Eq. (2) is broken down using standard financial statement items. The sales

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revenue S_{CE}, COGS C_{CE}, and SG&A G_{CE} in Eq. (2) are generally available as financial data. In contrast, intermediate goods costs I_{CE} are not separately identified in financial statements and must therefore be estimated by reclassifying financial statement items, depending on company-specific accounting practices and data availability. Based on financial data, intermediate goods costs refer to goods used in production—such as material costs, component costs, consumables, outsourcing costs, energy costs, logistics costs, and external service costs.

Table 1 shows the CE-business-related financial data used in this trial calculation for a waste management company. All values are dummy data. For simplicity, the definition and granularity of COGS and SG&A were aligned with the terminology used in the 2023 Basic Survey of Small and Medium Enterprises conducted by Japan's Small and Medium Enterprise Agency (SMEA). Accordingly, the cost of goods purchased and raw material costs, outsourcing costs, and freight and packing costs were treated as intermediate goods costs, as shown in Table 1 [3]. Although intermediate goods costs can also include items such as energy costs, they are omitted here.

$$CVP = \frac{5-(1.5+0.5+0.1)}{(1.5+0.5+0.1+0.5+0.25)+(1+0.1+0.1+0.1+0.05+0.25+0.05)} \fallingdotseq 0.64$$

Based on the above, CVP can be calculated by extracting the CE-business-related portions of standard financial statement items.

Table 1 Financial data used in the trial calculation (Unit: M$)

Sales revenue		**5**
Cost of goods sold (COGS)	**Cost of goods purchased and raw material costs**	**1.5**
	Labor costs	**0.5**
	Rent expenses	**0.1**
	Outsourcing costs	**0.5**
	Depreciation expenses	**0.25**
Selling, general, and administrative expenses (SG&A)	**Personnel costs**	**1**
	Rent expenses	**0.1**
	Freight and packing costs	**0.1**
	Advertising expenses	**0.1**
	Entertainment expenses	**0.05**
	Depreciation expenses	**0.25**
	Taxes and public dues	**0.05**

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Prior research has clarified several important aspects of CVP [2]. For example, in the remanufacturing use case, while CVP showed a positive correlation with operating profit, Circular Material Productivity (CMP)[4]—developed by the World Business Council for Sustainable Development (WBCSD)—remained largely unchanged. This contrast reflects the different evaluation perspectives of the two indicators. These results indicate that CVP can serve as a complementary indicator to existing CE indicators. When used alongside those indicators, it enables a more balanced assessment of circular strategies. Furthermore, combining CVP with other CE indicators is also essential not only for comprehensive assessment but also for preventing greenwashing and ensuring the credibility of CE strategies. In addition, it is important to recognize that when conducting evaluations using CVP, differences among industries in financial structure and cost structure may affect the results. For that reason, it has become clear that normalization is necessary to fairly and meaningfully carry out cross-sectoral CVP comparisons.

3. Application to Value Networks (VN)

3.1 VN diversity and calculation approach

As noted in the Introduction, CE business models often involve VN in which multiple companies collaborate to create value. Because CVP is calculated based on the common financial concepts of value added and expenditure, it is expected to be applicable not only to the evaluation of individual companies but also to VNs. This section analyzes VN configurations and describes the resulting calculation approach.

3.1.1 Diversity of VNs

VNs can take various forms, as described in ISO 59010 and ISO/TR 59032 [5–6]. Figure 1 shows several example configurations. The dashed area indicates the VN boundary; A, B, and C denote participating companies; and arrows represent resources circulating within the VN. In Fig. 1(c) and (d), different arrow colors indicate that the form of the resource changes—for example, combustible waste being converted into energy. Resources include not only products, components, and raw materials but also energy, information, and other forms.

Type 1 (Fig. 1(a)) represents a VN in which the form of the resource does not change. An example is the collecting (Company A), sorting (Company B), and refining (Company C) of iron scrap. Type 2 (Fig. 1(b)) represents a case in which the focus resource is closed within the boundary. ISO 59010 also introduces cases in which part of the resource loop is closed within the boundary. Type 3 (Fig. 1(c)) illustrates a case in which the resource changes form within the VN. At Company A, the resource splits into two types; at Company C, one is converted into another resource and transferred to Company B. An example of this situation would be one where Company C can convert combustible processing residue into energy and Company B can use that energy to convert the resource from Company A into

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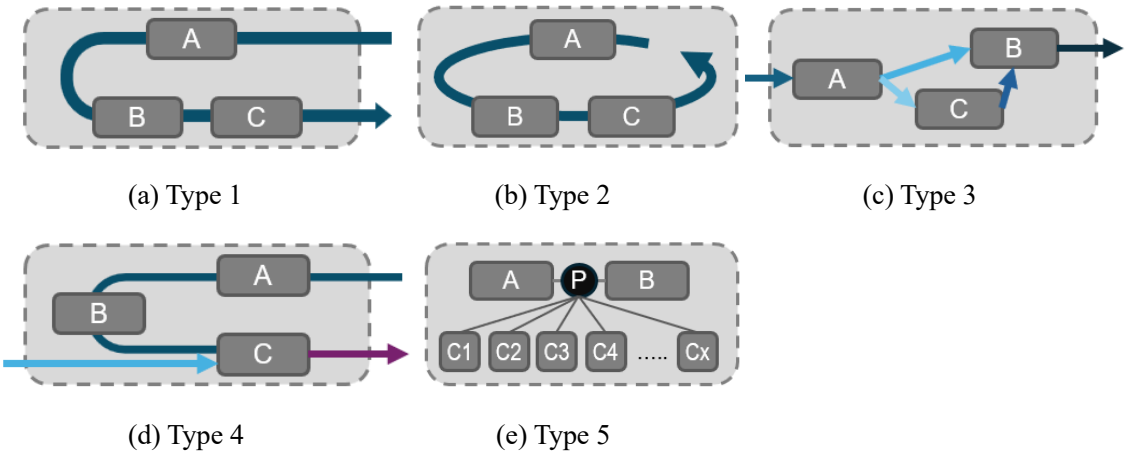

(a) Type 1 (b) Type 2 (c) Type 3

(d) Type 4 (e) Type 5

Fig. 1 Conceptual diagrams illustrating example VN configurations

another useful resource. Type 4 (Fig. 1(d)) illustrates a case in which, at Company C, the focused resource is combined with an external resource and converted into a different resource. Type 5 (Fig. 1(e)) represents a platform-based VN in which Companies A and B operate a CE platform P and an unspecified number of members C1–Cx participate. In this case, transactions between each member Ci and the platform P involve only information and monetary flows, while goods also circulate directly among the Ci.

As shown above, VNs can take various forms. The configurations in Fig. 1 are simplified examples that extract part of a VN; in practice, multiple types (Types 1–5) are often combined in more complex ways.

3.1.2 How to calculate CVP for a VN

When calculating CVP for an individual company, one can organize value added and expenditure consistently by defining the evaluation scope as the company itself or a specific business within the company. In contrast, because multiple companies collaborate to create value in a VN, defining the evaluation scope as a specific company or business makes it difficult to appropriately capture what value the VN creates as a whole. Therefore, an important perspective for considering value added generated by a VN is to focus on the resource that is the target of value creation across multiple companies. From this perspective, we considered the following three approaches for calculating CVP for a VN.

Method 1: Each participating company individually calculates the CVP related to the resource targeted by the VN. This is the same as calculating CVP for an individual company. If a single VN-level CVP is desired, the average or weighted average of the participating companies' CVP values is computed.

Method 2: Treat the VN as a single company and calculate its CVP.

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Method 3: Aggregate each company's value added and the costs required to generate it, and compute CVP as total value added divided by total cost.

In calculation Method 1, the result remains, in essence, a set of company-level CVP values and therefore does not represent the CVP of the VN as a whole. In calculation Method 2, resources that circulate within the VN boundary, such as the case shown in Fig. 1(b), cannot be handled appropriately, and the internal circulation structure of the VN cannot be evaluated properly. Accordingly, from the perspective of regarding the VN as a single production system, this report adopts calculation Method 3, which aggregates value added and expenditure across the entire network. However, applying CVP to a VN requires an additional interpretation of Eq. (2). Specifically, under calculation Method 3, each participating company or organization calculates Y_{CE} and E_{CE} for the CE activities associated with the VN, and these values are aggregated across the network. In doing so, to prevent double counting of expenditures within the VN, the purchase costs C_{D} of resources exchanged within the VN—including materials, products, services, and information—need to be excluded from the denominator (i.e., from the COGS in the expenditure term). The resulting expression for applying CVP to a VN is given below.

$$CVP_{\mathrm{VN}} = \frac{\sum(S_{\mathrm{CE}i} - I_{\mathrm{CE}i})}{\sum(C_{\mathrm{CE}i} + G_{\mathrm{CE}i}) - \sum C_{Di}} \tag{3}$$

In this equation, the subscript i denotes an index identifying each participating entity in the VN, and the summation is taken over all participating entities. The reasoning for excluding the purchase costs C_{D} of resources exchanged within the VN from the denominator is as follows. Figure 2 illustrates the conceptual flow of resources and money within a VN for Type 1 as an example. When goods or services move between companies within a VN, the revenue for one company is recorded as an expenditure for another. If each company's expenditures are simply summed to obtain the VN's total expenditure, the costs associated with resources exchanged within the VN are added multiple times. For example, as shown in Fig. 2, if a resource is transferred from Company A to Company B and then to Company C, Company B's expenditure includes Company A's cost, and Company C's expenditure includes the cost through Company B. Simple aggregation would therefore record the cost attributable to the same resource multiple times at the VN level, which is not appropriate when evaluating the VN as a production system. Based on this reasoning, this report excludes the purchase costs of goods and services exchanged within the VN from the denominator when estimating the VN's total expenditure. This enables evaluation, without duplication, of the relationship between the substantive expenditures jointly incurred by companies constituting the VN and the value added created in response. This approach is based on the same concept as eliminating intra-group transactions when preparing consolidated financial statements [7].

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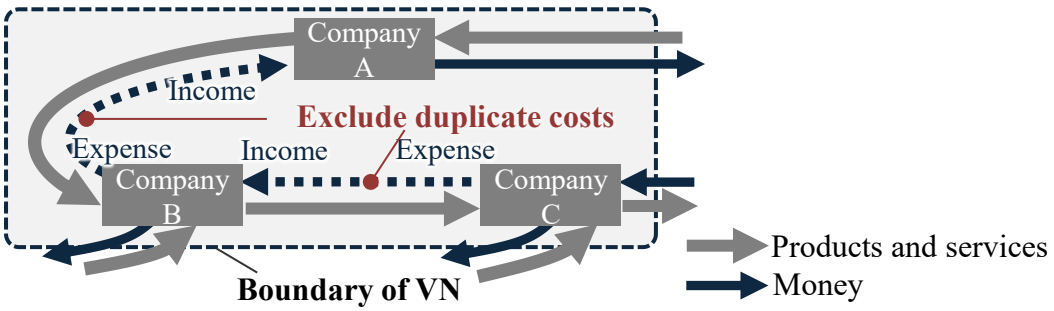

Fig. 2 Conceptual diagram of resource and monetary flows within a VN

Note that under this approach, the resources purchased by Company A in Fig. 2 are external transactions and can, in principle, be included in the denominator. However, including them could make Company A's cost tend to appear relatively large when evaluating the distribution of costs and value added among companies in the VN. In the calculation example in the next section (Section 3.2), we excluded this cost, considering its effect on distribution analysis; this point will be examined further using real data in the future.

3.2 Example application of the formula to a VN

To illustrate a concrete calculation example of VN-level CVP based on the formula proposed in Section 3.1, this section presents a trial estimation for a hypothetical recycling business. Figure 3 shows an example VN for the recycling business used in the trial. This VN operates a collection system limited to a specific material and consists of the following three interdependent companies.

- Collection company: Collects end-of-life (EoL) products, extracts materials of a specific quality, and sells them to the recycling company
- Recycling company: Shreds the materials purchased from the collection company to an appropriate size, removes impurities through sorting, then sells scrap to the material company
- Material company: Refines and processes the materials purchased from the recycling company and sells high-quality recycled material to manufacturers

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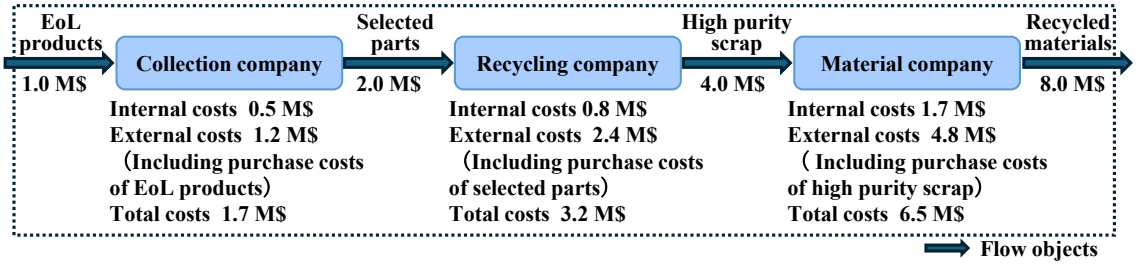

Fig. 3 Example VN of the recycling business used in the trial calculation

Table 2 shows the financial data for each company. All values are dummy data. The VN calculation was performed based on Eq. (3) using the following Steps 1–3.

Step 1 – Calculate the numerator of VN-level CVP, i.e., value added. Value added is the total of CE sales revenue minus CE external payments in Table 2.

$$Y_{\mathrm{CE(VN)}} = \sum S_{\mathrm{CE}} - \sum I_{\mathrm{CE}} = 14.0 - 8.4 = 5.6 \text{ M\$}$$

Step 2 – Calculate the denominator of VN-level CVP. The denominator is the total of CE total costs minus the resource purchase costs within the VN in Table 2.

$$E_{\mathrm{CE(VN)}} = \sum (E_{\mathrm{CE}} - C_D) = 0.7 + 1.2 + 2.5 = 4.4 \text{ M\$}$$

Step 3 – Calculate VN-level CVP, CVP_{VN}.

$$CVP_{\mathrm{VN}} = \frac{5.6}{4.4} = 1.27$$

If double counting is ignored, the denominator becomes 11.4 M$, and CVP_{VN} decreases to 0.49. In addition, in calculations of the standalone CVP for each company, the values are similar (0.47, 0.50, and 0.49), indicating that the benefits of the VN are distributed relatively evenly in this example.

These results show that, for VN-level evaluation, excluding internal costs is necessary because otherwise, CVP is underestimated due to duplicated internal costs. Although the trial calculation uses dummy data, the proposed method enables calculation for this VN, indicating that CVP can be applied to VNs.

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Table 2 Financial data for each company used in the trial calculation (Unit: M$)

Role	CE sales revenue S_{CE}	CE external payments I_{CE}	CE total costs E_{CE}	Resource purchase costs within the VN C_D
Collection	2.0	1.2	1.7	1.0
Recycling	4.0	2.4	3.2	2.0
Material	8.0	4.8	6.5	4.0
Total	**14.0**	**8.4**	**11.4**	**7.0**

3.3 Using CVP in a VN

As with company-level use, CVP can be used in a VN when judging which CE measures are effective or when making investment decisions for transitioning to CE. The VN-specific utility of CVP is discussed below. CVP is useful for evaluating the economic viability of a VN. For example, if a VN's CVP remains low, it suggests low economic rationality and can raise concerns about long-term viability. Even when a VN's CVP is sufficiently high, the distribution of value added and costs among participating companies can be highly skewed. This does not necessarily imply a structural problem, but understanding the underlying drivers is important when considering VN design and sustainability.

Calculating VN-level CVP requires determining value added and costs for each participating company, but it is not necessarily required to disclose these figures to all participants. A method in which a trusted, impartial third-party organization collects data from individual companies and calculates CVP can enable evaluation without public disclosure to the entire VN. Such efforts are expected to help prevent large imbalances in benefits and burdens within the VN. A third-party body can exist outside the VN, or it can exist within and become part of the VN's formation.

4. Future issues

As described above, we confirmed that CVP can be applied to both individual companies and VNs. However, several issues remain when considering practical implementation. This chapter outlines future issues that should be examined.

4.1 Issues in applying CVP at the single-company level

Based on the characteristics and limitations identified in prior studies, this section summarizes potential issues that may arise when applying and operating CVP in practice.

4.1.1 Definition of CE activities

As shown in Eq. (1), CVP evaluates only the value added and expenditure related to CE activities.

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Therefore, the question of which businesses or activities are identified and classified as CE activities has a major influence on the results. For multi-business companies, in particular, the definition of the CE scope can easily become arbitrary—a result that may impair the comparability and explainability of CVP. In applying CVP, it is important to clarify the definition of CE activities in advance and to operate consistently using the same criteria over time.

4.1.2 Greenwashing

Because CVP is an economically oriented indicator, it does not directly evaluate resource circularity rates or the reduction of environmental impact. Therefore, if assessments of CE progress or validity are based solely on CVP values, the results may not adequately reflect the actual state of circularity.

Prior studies have shown that CVP is complementary to existing CE indicators (e.g., CMP) and that it is necessary to perform evaluations by combining multiple indicators rather than using CVP alone [2]. In practice as well, it is necessary to use CVP together with other environmental indicators and to interpret the results with due care.

4.1.3 Differences in financial structures by industry

Because financial structures differ substantially by industry and business model, one should be cautious when simply comparing the absolute value of CVP across companies. Prior studies confirmed, using ordinary industry-segmented financial data that include non-CE businesses, that differences in financial structures can lead to large differences in CVP level by industry [2]. Accordingly, when using CVP at the company level, it is effective to compare against industry averages or the company's own historical performance, or to use normalized metrics. In particular, for cross-industry comparisons, it is preferable to focus not on the CVP value itself but on relative positioning or time-series changes.

4.2 Issues in applying CVP to a VN

4.2.1 Resource transformation

When the focused resource changes during circulation within the VN (e.g., Fig. 1(c) and (d)), no major issue arises as long as the change is completed within the VN. However, caution is necessary if new resources or components are introduced from outside at an intermediate stage and the nature of the resource under evaluation changes substantially. In particular, if the costs and value of externally introduced resources become dominant compared with the resources previously handled within the VN, the VN's overall CVP will approach the CVP of that company and will not represent an evaluation of the VN's overall value-creation structure. In such cases, this may undermine the intent of the indicator—evaluating the VN as a production system. Possible countermeasures for cases in which the resource changes substantially include: (i) adjusting the boundary used in the CVP calculation and excluding the conversion process from the evaluation scope; and (ii) clearly defining the state of the resource to be evaluated and estimating value added and costs based on that state to calculate CVP. This issue should be further examined based on the accumulation of VN case studies in the future.

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4.2.2 Participation by unspecified numbers of actors

In platform-based VNs, as in Fig. 1(e), participation may extend beyond a limited group of companies to involve an unspecified number of companies and individuals. In such cases, it is difficult in practice to capture and aggregate costs and value added for all participants. Within the CVP framework, this issue can be addressed in practice by defining a narrower evaluation boundary for CVP calculation than the conceptual boundary of the VN and excluding the unspecified participants from the calculation. However, when disclosing VN-level CVP externally, it is necessary to accurately disclose the boundary and calculation method used.

5. Acknowledgements

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