The Combination-Permutation Algorithm: Optimizing Portfolio Allocation with TOC and Cost of Time [1]

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Introduction

This article aims to answer these questions: what is the purpose of a portfolio of initiatives within an organization and how should resources be allocated to best achieve that purpose?

We will define the portfolio as a group of initiatives (projects and programs) that share common resources. Allocating resources to one initiative limits their availability for others. These initiatives may also have additional interdependencies beyond resource sharing.

I'm going to describe a method for portfolio allocation whose name may sound intimidating, but as you'll see, the concept is simple.

The Goal of Portfolio Allocation

People create systems—such as organizations—to achieve specific goals. Therefore, an organization's resource use should serve its goal. The effect of investing resources in a portfolio can be assessed by its contribution to the organization's goal, for example: for a business—its contribution to profit; for a nation—its contribution to the growth of the UN Human Development Index.

In the *Theory of Constraints (TOC)*, Goldratt defines the goal of a business as "to make money now and in the future." He proposes measuring this using three key indicators: *Throughput*, *Inventory*, and *Operational Expense* [1, 2]:

- **Throughput**: The rate at which the system generates money through sales—calculated as sales revenue minus truly variable costs (e.g., raw materials).
- **Inventory***:* The total money invested in things the system intends to sell, including raw materials, work-in-process, finished goods, equipment, and other assets.
- **Operational Expense**: All the money spent to turn inventory into throughput (e.g., salaries, rent, utilities).

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These three factors contribute to the ultimate goal of the organization— generating profit now and in the future. To ensure sustainable profitability, the focus, as Goldratt points out, should be on *Throughput*, since it drives revenue and has unlimited growth potential. *Inventory* management takes second priority, helping to free up cash and lower carrying costs. Third is *Operational Expense* management, which also affects overall profitability. [1]

Thus, a portfolio can contribute to the organization's goal through one or more of the following four changes:

- Increasing sales (or increasing delivered value)
- Reducing truly variable costs
- Reducing *Inventory*
- Reducing *Operational Expense*

The total effect is not simply the sum of improvements but rather the result of trade-offs between them. A project increasing *Throughput* might require an investment in new assets, thus increasing *Inventory*. The goal is not zero *Inventory*, but the minimum necessary to maximize *Throughput* and profit.

How should we allocate resources based on these criteria? In practice, these four factors can be integrated in a single criterion: **initiative (or project) profit**—and, by extension, **portfolio profit**. This criterion refers to the initiative's or portfolio's contribution to the organization's profit by increasing sales (or delivered value) and/or reducing truly variable costs, inventory, or operational expense. This interpretation aligns with the concept of "project profit" as used in the *Earned Profit Management* method [3]. It does not represent accounting profit but rather contribution to the goal of the organization.

This raises an important issue: treating profit as a single criterion gives equal weight to all four types of changes. Yet, as previously discussed, these differ in their contribution to long-term sustainability.

There are two possible solutions:

1. Include only initiatives that increase *Throughput* in the portfolio.
2. Prioritize initiatives that increase *Throughput* first, then those that impact *Inventory* and *Operational Expense* as secondary and tertiary considerations. If the initiatives within the portfolio address the system's constraint—as they ideally should— this prioritization

will occur naturally. Moreover, investment in an initiative should only happen if the constraint cannot be addressed in an easier or faster way.

By applying one of these two approaches, we can now define the portfolio's goal as *maximizing profit within the context of limited resources*.

The Constraint

The next question to address is how to allocate portfolio resources among individual initiatives in order to maximize portfolio profit.

We could potentially use a *constraint management* metric, such as *throughput contribution per unit of time of constraint usage* [1].

But in this case—where exactly is the constraint? By influencing the organization's constraint, we expect the portfolio to contribute to the organization's goal of profit.

To implement the portfolio in the best possible way—and thereby impact the organization's constraint—we must best utilize the constrained resource for portfolio implementation. That is, we must maximize portfolio profit per unit of constrained resource available for portfolio implementation.

Let's start by reviewing the financial resources allocated for implementing the portfolio. Do these constitute the actual constraint? In practice, financial resources for portfolio implementation represent a portion of the organization's current and future profit, reinvested to ensure sustainable long-term profitability. The size of this reinvestment depends on both needs and capabilities.

While financial resources are always finite, are they genuinely the limiting factor in the portfolio implementation system?

Regardless of the available financial resources, portfolio implementation requires tangible inputs such as skilled personnel, equipment, materials, information, etc. It is reasonable to expect that one of these resources will constitute the constraint in the implementation system—the one whose demand most exceeds its available capacity.

Even when resource demand appears to be lower than capacity, it is often still impossible to complete all planned initiatives simultaneously and on time.

Even if all initiatives are outsourced to external contractors with theoretically sufficient resources, a constraint may still exist within our system. I have managed such portfolios—and in fact, I myself have been the constrained resource. In other words, the constraint may reside in a specific portfolio management resource.

For now, we can formulate the constraint management requirement as *maximizing portfolio profit within the available capacity of the implementation constraint.*

The Cost of Time

Let's return to the *throughput contribution per unit of constraint usage*. As discussed earlier, we can generalize this to "profit contribution," resulting in *Profit Contribution per Unit of Constraint Use (PCUCU)*.

Now, imagine the following scenario: For the next six months, we have identified three potential projects that are expected to contribute most significantly to the organization's profit. During this period, the portfolio constraint can be used for 140 days, which represents its available capacity.

Table 1: Profit Contribution per Unit of Constraint Use (PCUCU) for Three Projects

Project	Expected Profit	Constraint Use	PCUCU (Profit/Days)
A	$28.0 million	70 days	$0.40 million
B	$18.0 million	60 days	$0.30 million
C	$13.2 million	60 days	$0.22 million

To stay within the constraint's capacity, only two of the three projects can be included in the portfolio. According to the PCUCU rule, the optimal choice is the combination of Projects A and B, with implementation starting with Project A—or more precisely, using the constraint first to Project A, then to Project B. This sequence yields the maximum portfolio profit of $46.0 million.

However, let's assume that Project A develops a fashion collection for the upcoming summer, Project C for the fall, and Project B for the winter. If Project C is not completed within the next six months, its expected profit will drop to no more than $3.0 million.

Project B's expected maximum profit remains unchanged if it's completed within the next nine months. But if it's finished too early (within six months), its maximum profit would drop to $9.0 million due to the rapid obsolescence of designs.

Therefore, for the next six months, the optimal selection is Projects A and C. Following the same reasoning, the constraint should be used first for Project A to ensure its full profit—indicating it has a higher scheduling priority than Project C.

This leads to the conclusion that when the *Cost of Time* [4] matters, maximizing portfolio profit requires not just selecting the right **combination** of initiatives, but also determining the optimal **permutation**—a specific implementation sequence of portfolio initiatives. By minimizing the portfolio's overall *Cost of Time*, we maximize the profit from the best investments.

To clarify the meaning of "permutation," coffee followed by cake is one specific permutation, and cake followed by coffee is another one. But coffee and cake at the same time is not a permutation. It's a feast!

To account for the *Cost of Time*, we need to develop *cost-of-time profiles* for each initiative, showing how expected profit varies with completion date. Such a profile can be developed through market analysis, historical data, expert judgment, and algorithmic models.

Here is an example of such a profile (the given periods are in *weeks*):

Table 2: Cost-of-Time Profile – Variation of Expected Project Profit vs. Completion Date

-5 w	-4 w	-3 w	-2 w	-1 w	Due date: Apr 1, 2027	+1 w	+2 w	+3 w	+4 w	+5 w
+$190 K	+$260 K	+$250 K	+$200 K	+$100 K	0	-$200 K	-$400 K	-$600 K	-$900 K	-$950 K

You wouldn't want your favorite fashion brand to delay its collection, would you? If you still doubt that this could happen, send them this article and the issue will be resolved!

The Combination-Permutation Algorithm (CPA)

The following steps outline the algorithm to ensure an allocation that maximizes portfolio profit:

Step 1 – Identify Candidates

Identify candidates for inclusion in the portfolio—initiatives that best address a small number of current and anticipated future organizational constraints. This should be accompanied by an assessment of each initiative's expected profit.

Step 2 – Identify Portfolio Constraint

Determine the total investment resource available for the portfolio, and identify the constraint (i.e., the limiting resource) for its implementation, along with that resource's available capacity.

Step 3 – Assess Needs

Assess each potential initiative's demand for the constraint, including both the required share of its capacity and the time period over which it will be used.

Step 4 – Identify Feasible Combinations

Identify all feasible combinations of initiatives—those that do not exceed the available investment resource and the constraint's capacity.

Step 5 – Develop Cost-of-Time Profiles

Develop *cost-of-time profiles* for each initiative within the feasible combinations.

Step 6 – Identify Permutations

Identify all possible permutations—implementation sequences—for each feasible combination of initiatives. Stage and parallelize initiatives based on their dependence on the constraint. Where necessary, account for other interdependencies. Then, calculate the expected portfolio profit for each permutation.

Step 7 – Select Optimal Solution

Select the specific **combination and permutation** that yields the highest expected portfolio profit.

Once the initial portfolio allocation is complete, the process can proceed with:

- Portfolio optimization by shortening its *Critical Chain*, thereby reducing the overall implementation time.
- Tracking portfolio implementation and optimizing performance through the *Earned Profit Management* method.

Conclusion

This article introduced the **Combination-Permutation Algorithm (CPA)**—a method for portfolio allocation grounded in the *Theory of Constraints* and the *Cost of Time*.

The possible ways to allocate portfolio resources are virtually unlimited, and the factors influencing portfolio outcomes are in constant flux. Therefore, perfect allocation remains an unattainable ideal.

Yet, this method ensures an effective resource allocation by:

- Defining the allocation goal and its measurement.
- Focusing on the system's constraint.
- Accounting for the portfolio's implementation constraint and the cost of time for individual initiatives.
- Providing guidance for ongoing portfolio optimization.

References

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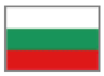

Alexander Apostolov holds a Master's degree in Economics and a PhD in Project Management and Sustainable Development. He has 25 years of experience in project management for new product development, construction, IT, events, and more.

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