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**Working Capital Exposure: A Methodology to Control Economic Performance in
Production Environment Projects**

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Abstract

The Cost-Time Profile (CTP) is a tool that presents graphically the accumulation of direct costs on a product as it moves through the manufacturing process. CTP incorporates the time dimension to the cost accumulation, and the area under the CTP curve is the Cost-Time Investment (CTI). In this paper we propose a new measure, derived from the CTP: The Working Capital Exposure. It will be calculated valuing the times and money amounts in which the company worked with their own money at a certain rate, and the areas of the graph in which the company worked with the client's money at a different rate. It will show for how long and for how much was the company exposed when working in a project with their own money instead of the customer's money. The associated risks will be discussed and further possibilities for probabilistic research will be presented.

Keywords: Cost-Time Profile, Working Capital Exposure, Project Management, Cost, Investment.

1. Introduction

Operating managers have usually viewed investment as a static number, \$20 million, \$200 million, and so on. As a static entity, investment is difficult to manage. One good example is inventories, which require extraordinary efforts to obtain reductions of even a few percentage points. Speaking dynamically, investment is the flow of cash over the cycle time of the business process. It can be measured as cost per unit of time over time.

In this paper, we revisit the *Cost-Time Profile* (CTP) (Fooks, 1993), a graphical representation of how much money is spent on the manufacture of a product and for how much time it remains invested before being recovered via sales. The CTP presents cost and time data, instead of operating procedures or systems, therefore making it an interesting complement to Value Stream Mapping (Rother and Shook, 1998; Barker, 1994) for the complete representation and monitoring of a manufacturing system.

Also, the area under the curve in the CTP represents the *Cost-Time Investment*, which has many similarities to any regular investment. The Cost-Time Investment impacts the bottom line by revealing hidden working capital requirements. This fact makes the Cost-Time Investment an important indicator of the use of resources in the manufacturing of a product.

The uses and applications of both the Cost-Time Profile (CTP) and the Cost-Time Investment (CTI) are all related to the simultaneous visualization of the Cost and Time dimensions and *their interactions*. There will be a discussion of these applications in subsequent sections

However, when selling discrete products the costs dominate all the manufacturing and logistics processes, and the company perceives revenues only at the very end of the cycle, when payment from customers is received. In project management we have a different situation, since it is possible to receive cash advances even before incurring in any cost and in intermediate points during the life of the project, so it is necessary to assess the economic status of the project *at any moment of its duration*. For this purpose we develop the **Working Capital Exposure** (WCE), which presents the economic position of the project at any discrete point in time and is able to represent cash advances at any moment and follow their impact on the management of the project.

In this paper the concepts and construction of the Working Capital Exposure (WCE) are presented through the use of a numerical example. Potential applications and transfer to other areas of Industrial Engineering and Manufacturing are discussed, and questions to stimulate future research directions are formulated.

2. The Problem

Traditional product costing captures the product-related expenditures in a simple additive manner. One of the biggest teachings of the use of Value Stream Maps has been the discovery that the time it takes a product to flow through the process is usually much longer than it should. This discovery highlights the importance of considering the time dimension and the time-value of money on the costing of a product.

To address these two problems, the Cost-Time Profile (CTP) was developed (Fooks, 1993). However, CTP handles easily the addition of costs without the alternation of revenues or advances, therefore making it inconvenient to handle projects. It also does not consider overhead, which can be an important part of project expenditures. The problem then becomes to develop a tool to report the economic status of the project “in real time” to include the occurrence of cash advances and the consideration of overhead. This tool, called Working Capital Position (WCE), is derived from CTP. CTP will be presented in the next section and from there the development of WCE will be presented.

3. Definition of Cost-Time Profile

A Cost-Time Profile is a chart that presents the Accumulated Cost at any moment in the manufacturing of a product. **Figure 1** shows an example of a Cost-Time Profile.

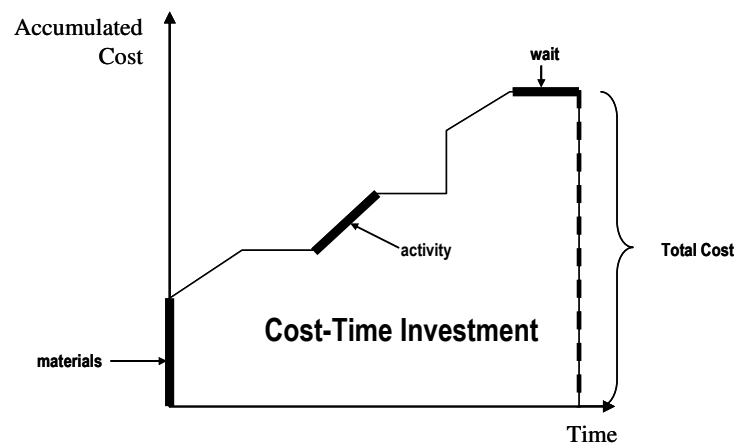


Figure 1: Example of a Cost-Time Profile

The CTP curve has different types of elements (Rivera and Chen, 2006-1):

- *Activities:* The Activities are represented as ascending lines (positive slope), since at each unit of time the total accumulated cost increases. (*Assumption:* Activity Costs are uniformly distributed over the duration of the activity, unless they can be further dissected in the time dimension). For Project Management there will be a cost

component (overhead) that occurs every time unit even if no direct activity in the project is happening,

- *Materials:* The addition of Materials to the process is presented as a vertical line, assuming that materials are received “instantaneously”. This cost of materials will continue “un-recovered” until the end of the process.
- *Waits:* At certain moments in the process, no activity is being performed. Therefore, there is no active addition of cost to the Total Accumulated Cost and for this reason Waits are represented as horizontal lines (or “zero slope” lines). Waits are not very relevant for Project Management, because every day that passes generates costs due to payroll and overhead.
- *Total Cost:* This is the height of the graph at its ending. It represents the dollar amount that has been spent as cost in the manufacture of the product.
- *Cost-Time Investment:* The area under the CTP curve represents how much *and for how long* costs have been accumulated during the manufacturing process. It is the composition of the cost and time dimensions (Rivera and Chen, 2006-3).

4. Construction of the Cost-Time Profile

To properly build a Cost-Time Profile, several intermediate steps need to be accomplished. We need to know *when* the different components of the CTP happen. We also need to know *how much* does each of the component cost. Combining the knowledge of the previous two points we figure out *how much* does *every time unit* of the manufacturing process cost. Finally, with the information from the previous findings, we calculate the *Accumulated Cost*

at *every time unit*, and chart it to obtain the Cost-Time Profile and calculate the Cost-Time Investment.

For this case, we will follow an example with a simple project network with seven activities.

The necessary information is presented in **Table 1** and **Figure 2**.

Activity Id	Time (months)	Cost Rate (\$/month)	Materials (\$)
A	5	1,000	7,600
B	7	4,700	
C	6	1,800	
D	3	3,200	
E	4	2,500	8,900
F	12	3,900	9,400
G	6	1,100	

Table 1: Project network information

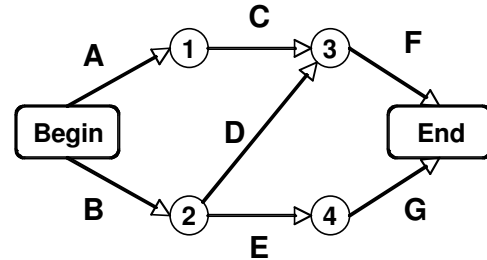


Figure 2: Simple Project Network

4.1. When do the components of the CTP happen?

Build the Process Map: The first thing to do is to describe the project, including the relevant activities, material releases and waits. This can be accomplished using a *Network Graph* such as those employed in Project Management representations (Hillier and Liebermann, 1995).

Figure 2 presents an example of such a graph.

Build the schedule of activities: The schedule of activities should present when each component of the Cost-Time Profile starts and finishes. In this case, this is a depiction of the current state of the process; therefore a simple Gantt chart can be used. **Figure 3** presents the Gantt chart for the example that is being presented here.

Id	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
A	10	10	10	10	10																		
B		47	47	47	47	47	47	47															
C						18	18	18	18	18	18												
D									32	32	32												
E														25	25	25	25						
F												39	39	39	39	39	39	39	39	39	39	39	39
G																		11	11	11	11	11	11
Materials																							
A	76																						
E																							
F	94																						
Overhead	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Monthly Cost Rate (00)	116	87	87	87	87	95	95	95	80	80	80	163	69	183	94	94	94	80	80	80	80	80	80

Figure 3: Gantt Chart for the example project

4.2. How much cost happens at each time unit?

Figure 3 presents the Gantt chart for the project, and also the cost rates for each component of the project. The first section presents the monthly cost rates for activities, then the cost of materials is presented at those moments where it happens, and finally the overhead rate is added. The last line (Monthly cost rate) presents the resulting cost to apply for each time unit (month)

4.2. How much Accumulated Cost do we have at each moment?

Building on the information from the previous points, it would be analogous to build a second array of the same dimension. In each position of the array, we would have the Accumulated Cost, basically the value of the previous position plus the cost increment in the corresponding time unit. **Figure 4** presents such an array.

Month	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Accumulated Cost (00)	116	203	290	377	464	559	654	749	829	909	989	1152	1221	1404	1498	1592	1686	1766	1846	1926	2006	2086	2166

Figure 4: Accumulated cost at each time unit

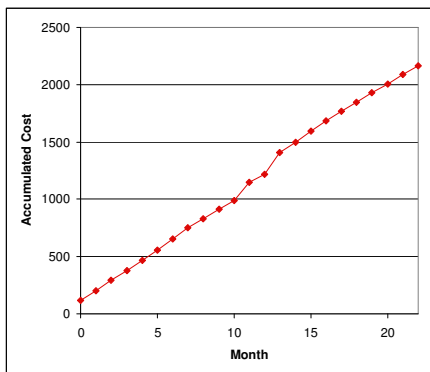
4.3. Cost-Time Profile

The **Cost-Time Profile** is the chart that presents the value of the Accumulated Cost at each time unit.

The **Cost-Time Investment** is the summation of all the positions in the array of Accumulated Cost. It is also the area under the CTP curve.

The **Total Cost** is the height of the Cost-Time Profile at its latest point in time. It is the Accumulated Cost at the last time unit. It represents the addition of the costs incurred during the process *without considering the time-value of money*.

Figure 5 presents the Cost-Time Profile for the example we have been following.



Total Cost = \$21,660

Cost-Time Investment = 2,648,800 \$-month

Applied Interest Rate = 10% (annual) = 0.7974% (monthly)

Direct Cost = $21,660 + (2,648,800 * 0.7974\%)$
= \$ 237,721

Figure 5: Cost-Time Profile Chart and related calculations for the Example case

4.4. Direct Cost.

The Cost-Time Investment represents a amount of money committed in the product during a certain period of time. This is analogous to securing a loan, where the user gets a sum and pays it back over time. In this analogy, the interest payments are the cost of having this money for a certain time; therefore we can use the same figure and apply it to the Cost-Time Investment. Because of this, we argue that the Direct Cost of the product should be calculated as follows:

$$DirectCost = TotalCost + (Cost-Time Investment * Applied Interest Rate) \quad (Eq. 1)$$

(Rivera, 2006).

Applied Interest Rate represents whatever interest rate the company deems appropriate to apply in this situation, be it the Internal Rate of Return, or the Cost of Capital, or a money market rate or any other the company chooses to use.

Direct Cost captures the total “dollar” amount spent on the project, plus the time value of money effect of the working capital invested in it.

5. Working Capital Exposure

5.1. Construction

The Direct Cost, found through the construction of the Cost-Time Profile, is found under the assumption that all costs and working capital investments happen before any income is received, as it is common for the manufacturing of tangible goods. This is not always the case for projects, in which cash advances can be received before the beginning of the project and during its development. It is therefore necessary to further develop a tool that presents the status of the investment in working capital at any moment during the duration of the project. This tool is what we call the **Working Capital Exposure (WCE)**. The WCE is analogous to finding the Direct Cost at each time unit. We will now present some notation and the construction of the WCE.

Notation

$IR = Applied Interest Rate$

$c_i = Cost that happens at time unit i$

$$AC_i = Accumulated Cost at time unit i; \quad AC_i = \sum_{k=0}^i c_k \quad (Eq. 2)$$

$$TC = \text{Total Cost (at the end of the project)}; TC = AC_N \quad (Eq. 3)$$

$$CTI_i = \text{Cost-Time Investment at time unit } i; CTI_i = \sum_{k=0}^i AC_k \quad (Eq. 4)$$

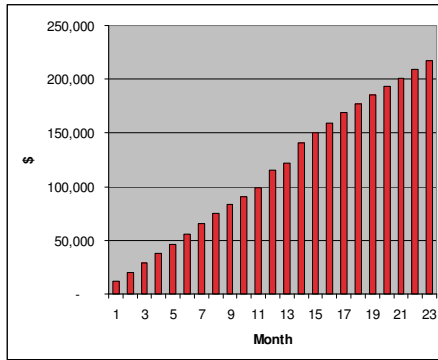
$$\text{Direct Cost : } DC = TC + CTI * IR \quad (Eq. 1)$$

Direct Cost, as calculated above, is valid when calculated at the end of the project. However, if we want to find the Direct Cost at any moment i during the duration of the project (WCE_i) we need to replace TC and CTI for their equivalent at a time i , so $TC_i = AC_i$ and

$$CTI_i = \sum_{k=0}^i AC_k . \text{ Replacing these in Equation 1 we get}$$

$$WCE_i = \text{Working Capital Exposure at time } i; WCE_i = AC_i + IR * \sum_{k=0}^i AC_k \quad (Eq. 5)$$

In **Figure 6** we present the chart and values for WCE_i for the example we are following. Notice that $WCE_{22} = DC$, which is obviously expected.



Month	WCPi
1	20,308
2	29,016
3	37,726
4	46,438
5	55,953
6	65,471
7	74,990
8	83,012
9	91,036
10	99,063
11	115,393
12	122,325
13	140,663
14	150,102
15	159,544
16	168,989
17	177,036
18	185,085
19	193,136
20	201,189
21	209,244
22	217,301

Figure 6: WPC for each time unit

5.2. Impact of cash advances on the WCE

The figure for Working Capital Exposure at the end of the example that we have followed so far is **\$217,301**. However, this figure is obtained considering only costs (as it was explained in CTP construction). It is not uncommon that projects receive cash advances before beginning

operations, at intermediate times during execution and after finishing operations. In this case, it is necessary to modify the formula for the WCE (Equation 5) to include the cash advances, considering a 30% profit margin on the project and then distributing the resulting price (\$310,431) in a \$100,000 advance at time 0, a \$100,000 advance at month 11 and the remainder of the money at the end of the project.

How will the WCE be affected by the presence of advances? We contend that the formula should be adjusted to consider the accumulated amount of money received through advances. We shall call R_i (revenue) the advances received at time unit i . Therefore, Equation 5 should be adjusted as follows.

$$WCE_i = AC_i + IR * \sum_{k=0}^i AC_k + \sum_{k=0}^i R_k \quad (Eq. 6)$$

Using this new definition, a comparative profile is devised (**Figure 7**). The line with triangular markers presents the new position (including the consideration of revenues) and the line with circular markers presents the WCE without the consideration of revenues.

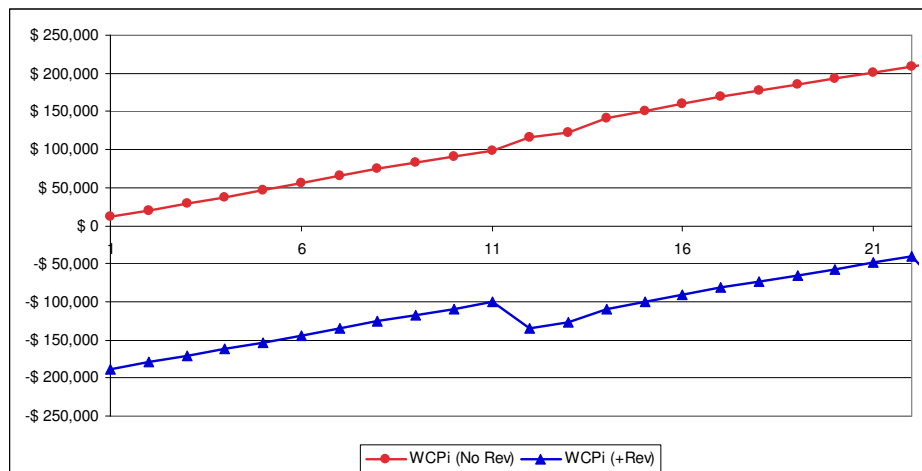


Figure 7: Working Capital Exposure (with and without consideration of Cash Advances)

An important remark can be made from this chart: In the case of WCP considering the cash advances, the position of the company is always negative, which means that throughout the duration of the project the company always worked using the capital of the client entity. This is the ideal scenario for a project-oriented company.

6. Conclusions and Future Research

6.1. The Working Capital Position at the end of the project is the profit obtained

In the example case, the final position reflects the difference between the total price of the project and the WCE without considering advances (Direct Cost in the CTP scheme). This was expected, and it is a useful tool to determine the profit obtained in the project.

6.2. The WCE reflects the “ownership” of the resources used

A positive WCE means that the working capital a company is using is of its ownership. A negative position means that there are still resources present from the cash advances and they have not been entirely consumed, therefore we are working with the client's money, which is the situation any company would like to find itself in. Also, it opens the possibility for estimating the effect of selling units at different moments in time, in the case of construction project, for example.

6.3. Variable Interest Rates

In high-inflation economies (such as those in several Latin American countries), it is common that the Central Bank increases interest rates as a mechanism to control the demand of money

(to control inflation). In long-term projects, the WCE would be affected as a result of the application of increasing rates (as the terms lengthen, the rates increase).

6.4. Cost of Capital Considerations

The use of a unique cost-of-capital rate for the project does not consider the variable nature of interest rates facing the expectation of profitability that investors have for different investment terms, that is, the term rate structure. Further research in this area is needed to investigate the impact of investor preferences and expectations on the WCE for projects designed for different durations (depending on the complexity and capital requirements).

6.5. The “Treasury Effect”

When negative positions ($WCE_i < 0$) happen, as a result of the cash advances received, it could be argued that the treasurer could put the “unassigned” money to work in financial markets, generating some financial income. This is called the “Treasury Effect”, and it would be highly desirable for a project-oriented company to generate the capability of putting the client’s money to work to generate some extra income for the project. Further research in this area is advised, as well in the estimation of the differential between the cost-of-capital rate and the rate of return expected in financial markets.

6.6. The effect of timing of the cash advances on the WCE

When cash advances during the execution of the project are considered it is necessary to study the impact of their timing on the WCE. Depending on the amount and time of reception of

these advances, the Working Capital Exposure on different moments will be affected and the exposition to use the company's resources or the client's resources will vary.

6.7. The impact of uncertainty on the WCE

Whereas productive environments for projects in areas such as variability present the execution times of activities, would be desirable to assess the possible behavior of the CTP and the WCE under conditions of risk and uncertainty. Could be used such techniques as Monte Carlo simulation to estimate the WCE of the projects.

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