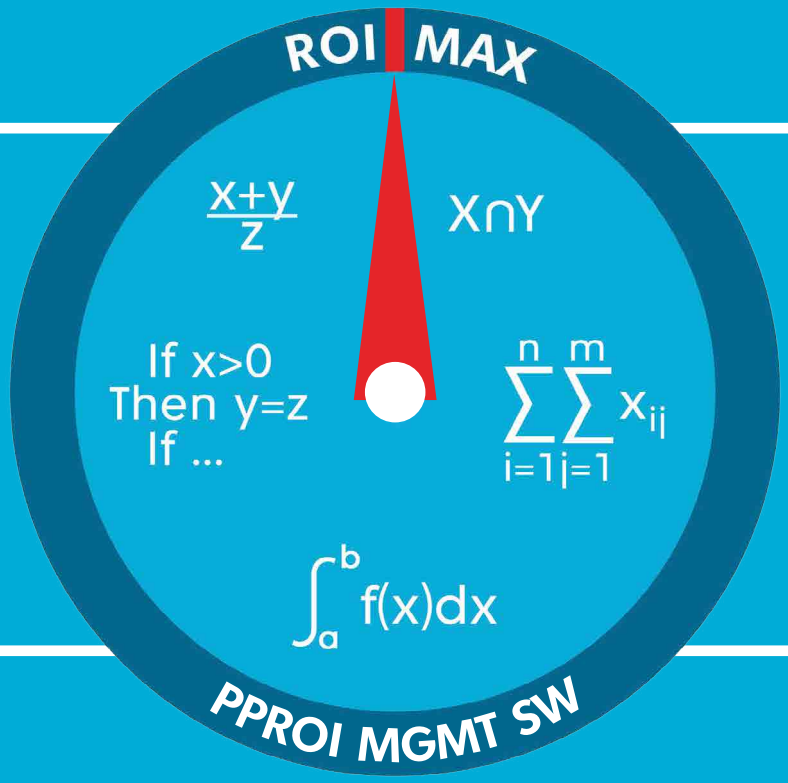
REVOLUTION IN ENTERPRISE FINANCIAL MANAGEMENT

MANAGEMENT BY OBJECTIVE - MAXIMIZING ROI

PPROI

Aligning
Products, Processes and Resources
to Maximize ROI



GROUNDBREAKING MANAGEMENT SOFTWARE

PPROI Enterprise Management Software

Supported by

T A
Č R

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https://www.mpo.cz/en/ www.tacr.cz/en

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The EU financial and expert support and co-financing of the technological development of PPROI by the TAČR and the MoIT of the Czech Republic, relate to the dissemination PPROI breakthrough software for the management of industrial enterprises, conditioned by the upgrade of its first generation which has been verified in practice and officially rewarded. We greatly appreciate this support.

Enterprise management and its results depend on the system of control information. The PPROI SW's unique features lie in the integration of the enterprise's objective with the means to achieve it. This is succinctly expressed in the words „Aligning products, processes and resources to maximize ROI ". The realization of this intention required the creation of new information system structures, the introduction of new key variables and the formulation of linkages of all elementary factors, so that they are gradually projected into a comprehensive criterion, the ROI of the enterprise.

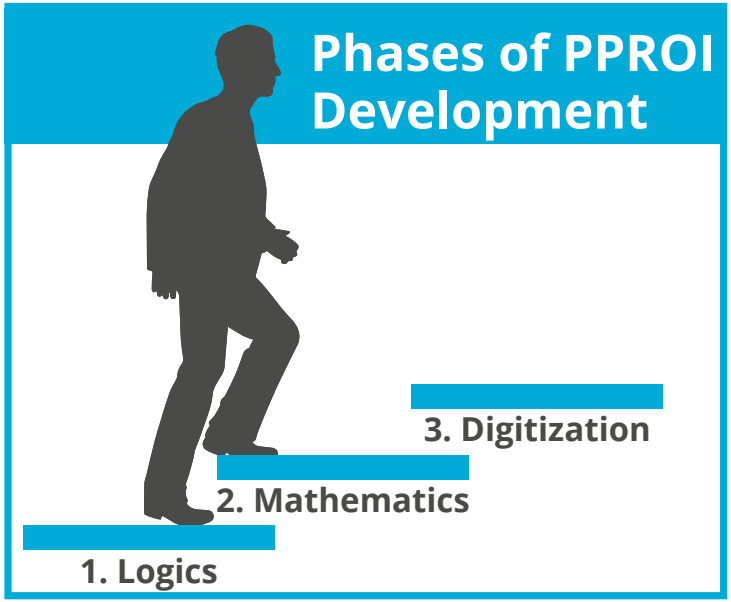
This was made possible by the application of methods and tools of mathematics not previously used in management. Digitalization has breathed life into math formulas. PPROI SW simulates the controlled behavior of the enterprise itself as an organism and navigates the enterprise to maximum efficiency. Emphasis is given to the calculations for the planning period to ensure timely reactions of managers to future situations.

For a new way of managers' education, appropriate to the current IT era, we have developed a Demo version of PPROI.

In a thorough explanation of the issues, we describe the unique features of PPROI specifically and openly as the dissemination of the system's ideas and procedures is of general benefit.

Authors

Groundbreaking PPROI Information on Processes by Products at a Glance



Management theory & ERP so far

Wrong pricing formula *Distorted*

Unknown $ROI = \frac{\text{Price – Costs}}{\text{Capital Employed}}$ *Unknown*

- Information darkness
  No financial information on machines & equipment, buildings and inventories
- Mismanagement, outside enterprise objective
- Large wastage of enterprise's capital to the general detriment

PPROI since 3rd millennium

OK *OK* *OK*

$ROI = \frac{\text{Price – Costs}}{\text{Capital Employed}}$

OK

- Comprehensive, interlinked, correct information on resources in processes
- Management aimed at the enterprise objective
- Maximum growth of enterprise capital for the common good

Everything in the enterprise is under financial control via brand new information

Dynamic planned projection of elementary parameters of products, processes and resources into
- **Costs, Capital employed and ROI of processes by product** *and ultimately into*
- **Enterprise ROI**

Managers think and act like investors, in the interest of investors and the enterprise's objective – they systematically pursue ROI maximization

Management enters the realm of science

Content

„If you cannot measure what you are speaking about, then it is not science.“ Lord Kelvin

“Everything should be made as simple as possible, but no simpler.” Albert Einstein

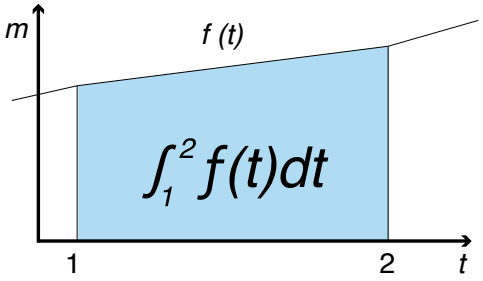
Executive Summary

Main reasons for PPROI development

$$ROI = \frac{Price - Costs}{Capital\ Employed}$$

PPROI SW was developed in the context of the introduction a lean manufacturing in order to maximize its efficiency - ROI, in response to the complete absence of key financial information in enterprise information systems – ERP. This refers to capital employed and ROI in processes defined by products that are subject of standard management. In addition, recorded product costs are partial and total product costing through overhead surcharges dramatically distorts reality. In this information darkness, managers grope, the management of the enterprise completely ignores its objective, there is a great wastage of the enterprise's capital. It has nothing to do with science. PPROI changes this unfortunate situation from the ground up, in many aspects. The Demo version of the PPROI SW demonstrates this.

Five from the PPROI's groundbreaking features



1. Two-dimensional measurement of capital employed by the definite integral
For the evaluation of any economic activity, the ratio of monetary yield to the stock and time of money involved in that activity is decisive. This is a basic financial principle. The simultaneous measurement of stocks and time of involved money mathematically enables the definite integral. In its graphical display as an area the money, M, is on the y-axis and the time, T, on the x-axis. The units of money and time determine the unit of a definite integral, expressing the moneytime, MT. E.g., if the unit of money is € and the unit of time is Year, the unit of moneytime is €Year. The definite integral is (implicitly) applied by banks in measuring the money balances on accounts, as a basis for determining interest. The application of a definite integral is also indispensable in the measurement of capital employed and ROI of processes by products.
PPROI calculates the capital employed in processes for a particular product by the sum of large numbers of definite integrals. The application of the definite integral has fundamental importance for the whole economic theory. This does not consider the two-dimensional variables in moneytime or quantitytime units at all. Therefore, the crucial economic problems do not have a correct solution.

2. Specificity of information on costs and capital employed by resources. No overheads
Even the distortion of product costs in their traditional calculations has a mathematical aspect. Overhead surcharges on the recorded components - direct materials and direct labor – assume that the „residual“ costs are linearly dependent on the recorded components. However, this is not the case in any context. The individual cost components generated by different resources are independent. For example, the cost components generated by machines in processing operations are completely independent of direct wages - the traditional basis for overhead surcharges. PPROI records all cost and capital employed components for specific resources.

3. Product pricing: Reflecting process requirements on capital employed
The principle of the proportionality of money yield to the stocks and time of money involved in a particular activity is also reflected in product pricing. Profit markups on product costs are proportional to the capital employed in the respective processes. The traditional cost-proportional profit markups deny a basic financial principle and lead to contradictions.

4. Math links all the elements resulting in enterprise ROI as a universal criterion
The elementary parameters of products, processes and resources result through sequences of mathematical functions in the costs, capital employed and ROI of processes by product and finally in the ROI of the enterprise. Costs and capital employed usually work inversely and therefore calculations of an enterprise's ROI as a universal criterion are necessary in all types of evaluation, in operational management, strategic decision-making and continuous improvement. Everything in the enterprise is assessed and managed by its objective.

5. Brand new crucial information for senior management
The financial performance of an enterprise is the responsibility of its senior management. However, it only obtains the necessary information from the financial accounting for the previous period and, moreover, not about the underlying causes. PPROI provides key information on the ROI of processes by product and, as a result, the enterprise ROI for the portfolio of products in the physical production plan. Thus, senior management can see early on the future weaknesses of the enterprise - products and processes with unfavorable ROI values - and can take timely and relevant actions.

Demonstration of Brand New PPROI Information Compared to ERP

Costs, Capital Employed and ROI in Processes for a Specific Product

Example

Product No. 3 **Period: 1. 6. 202 i – 31. 5. 202 i+1**

Product unit costs

Process phase	ERP	€	PPROI	€
Supply			Materials and services	2
			Labor	4
			Space	1,5
Production	Direct materials	30	Direct materials	32
			Process cooperation	2
	Direct labor	17	Direct labor	19
			Machine energy	9
			Masses, technical gases	4
			Tools	2,5
			Equipment maintenance	5
			Equipment depreciation	3
			Space	4
			Indirect materials and services	5
			Indirect labor	18
			Indirect space	3
Distribution			Materials and services	3
			Labor	5
			Space	2
Total				124

Electricity	5
Gas	3,5
Compressed air	0,5

Internal maintenance	3,5
External maintenance	1,5

Indirect costs and capital allocated to direct processes

Direct + allocated costs and capital for direct processes

Aggregate data

Price *€*	Costs *€*	Profit *€*	Capital employed *€Rok*	Profitability *€/€*	Capital turnover *Year*	ROI *€/€Year*
130	124	6	58	0,046	0,446	0,103

Capital employed per product unit

Process phase	ERP	PPROI	€Year
Supply		Buildings & land	4
		Movable assets	1
		Inventories	3
Production		Buildings & land	13
		Machines and equipment	16
		Buildings & land indirect	8
		Movable assets indirect	4
		Inventories	2,5
Distribution		Buildings & land	3
		Movable assets	1
		Inventories	2,5
Total			58

PPROI versus ERP

The fundamental benefit of PPROI compared to ERP, and previous financial product information in general, is clear from the tables. The PPROI - for the first time ever - contains complete information on the product costs components over a certain period, generated by specific enterprise resources. ERPs contain only traditional information on direct materials and direct labor. But even these are not correct, as they ignore the defectiveness of the manufacturing processes. PPROI reflects it. The tables also show the independence of the other components of product costs from direct materials and direct wages Traditional calculations of total product costs by overhead surcharges to recorded components are therefore illogical and misleading. ERP has no information on capital employed (abbreviated CE) in processes by product, which consequently also applies to the ROI of these processes.

Attributes of PPROI calculations

The data always refers to a specific period and the quantity of individual products in the period. Calculations are based on input information on products, resources and process phases, and on physically and organizationally defined parts of the enterprise, called territories in PPROI. The processes and territories through which product parts and the product itself pass are considered direct. The groups of data presented in the tables are formed by successive aggregations of more detailed data. The data in a particular group can therefore be split into more detailed groups, as illustrated by the breakdown of machinery energy and maintenance.

The processing cost components, mostly variable, are calculated for individual resources and their standard times in process phases. Fixed costs and CE in the phases are corrected by the time use of the respective resources in the period. Costs and CE defined for individual territories, are appropriately allocated to the phases of the direct processes in the period.

Management by Enterprise Objective Through Elementary Causes

PPROI concept and its realization

A unique feature of ROI is its comprehensiveness. The ROI defined for the operational activities of industrial enterprises responds naturally to all the parameters of the enterprise's products, processes and resources in their interrelationships. These parameters are determined by people and should be determined in such a way that together they result in the maximum ROI value. This implies two basic requirements for an information system:

- Providing an environment for recording the necessary elementary parameters of products, processes and resources
- Automatically projecting these parameters into an enterprise ROI value

If so, the enterprise's means may be managed by the enterprise's objective.
This logical concept was first formulated and technically implemented in PPROI.

PPROI as a living system

On the previous page, we listed the groups of costs and capital employed for the product and their projection into the aggregate product parameters, including ROI.

Drill No.	Purchase price €	Time of one use *Minute*	Number of sharpening	Price of one sharpening €
0358	50	30	4	10

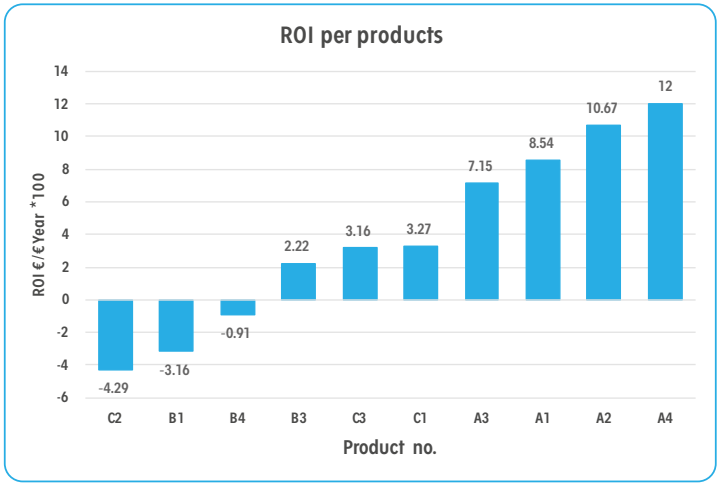
Now we will explain the recording and processing of elementary data using the example of a drill and a drilling machine. The person responsible for consumable tools records in PPROI the data in the table. The technologist sets the drilling time for the drilling operation of a specific part. PPROI calculates the cost of the drill bit per 1 minute of drilling from the data in the table and subsequently calculates the cost of the respective operation per drill bit from the drilling time. These costs of the operation are related to a specific resource and, through automatic PPROI calculations, enter into the successively aggregated cost components of the product, the ROI of the respective product and the ROI of the enterprise. If, for example, the price of sharpening a drill bit changes, the responsible employee enters the new price into PPROI and PPROI performs new calculations. Changing an elementary parameter of one resource changes the parameters of the whole system.
The situation is similar for the costs generated by the drilling machine. Here too the costs are mostly variable - electricity, lubricants, maintenance, etc., but depreciation is fixed.
The input to the variable cost calculations are the physical parameters defined for the drilling machine type per time unit of its activity. In addition, these are the prices of the resources consumed, including the price of electricity. From these inputs and the drilling time, PPROI calculates the variable cost components.
The depreciation of the drilling machine related to the respective operation is calculated by PPROI on the basis of the price of the drilling machine, its lifetime, the drilling time and the time utilization of the drilling machine in the planning period. The time utilization of the drilling machine is calculated automatically by PPROI. By analogy to depreciation, the capital employed in the drilling machine is calculated for the respective operation.
Prior to PPROI, the costs of the drill bits and drilling machine were included in the production overhead, proportional to the direct wages of the operators in the respective operation. This is nonsensical, misleading, and the effort spent on this costing is a waste of time.

Variable and fixed components of product costs in a broader context

Variable costs generated by machines and other equipment in processing operations include, among others, costs generated by handling robots whose active times differ from those of processing machines. The traditional components of variable costs are direct material and direct labor. All these components must be increased by standardized process defectiveness, which (with fluctuations around the standards) requires repetition of operations and, in the case of irreparable defects, an increase in the physical consumption of direct material and its costs. These costs are fully covered in PPROI. Reducing the standard defectiveness of any processing operation increases the enterprise ROI.
A substantial part of the product costs are indirect fixed costs. These depend on the absolute values of their components and on the quantity and structure of products in the plan of a certain period. PPROI also calculates these product costs components automatically from elementary input data and reacts to changes in these data.
Traditional calculations of fixed „overhead" costs of products by surcharges to recorded variable components are completely illogical and have no relevant solution.

Crucial Information to Senior Executives and Supervisory Board

Company ROI (Weighted Average)	ROI Simple Average	Capital Employed Structure Impact	Average Deviation
0.72	3.87	-3.15	4.58



Product	ROI *€/€Year *100*	Capital employed *€Year*	% of Enterprise's capital employed
C2	-4.29	3 562 000	4.32
B1	-3.16	18 609 000	22.57
B4	-0.91	20 489 000	24.85
B3	2.22	23 425 000	28.41
C3	3.16	4 288 000	5.2
C1	3.27	4 131 000	5.01
A3	7.15	1 542 000	1.87
A1	8.54	3 414 000	4.14
A2	10.67	2 358 000	2.86
A4	12	635 000	0.77

Planned ROI & Capital employed by products ⟶ Enterprise ROI

The basic tool for managing the enterprise is the plan, which contains information on the quantities of each product for planned period. Financial information should correspond to these products. The brand new essential information that PPROI provides informs on ROI and capital employed in processes by products and resulting enterprise ROI value.
PPROI provides this information in the report shown on the left. The executives can see which products, their processes and prices need to be focused on immediately. For a broader product portfolio, the data in the top reports may refer to product groups, broken down for individual products in the lower reports.

Variables in the report and their statistical characteristics

ROI values are multiplied by 100, i.e., expressed in the same way as the interest rate in banks.
The data in the table and graph are ranked from the lowest to the highest ROI value.
The capital employed in the processes for each product is expressed in the table for the quantities of products in the plan. These quantities vary. In the last column, the capital employed for each product is expressed as a percentage of the total capital employed in the enterprise.
The statistical characteristics above the graph provide condensed information about the dataset.

• An enterprise's ROI is computed as the average of the partial ROI values, weighted by the capital employed in the processes for the respective products; compared to the simple average of the values, it is lower by 3.15 due to the heavy weights of capital employed in the processes with low ROI values.

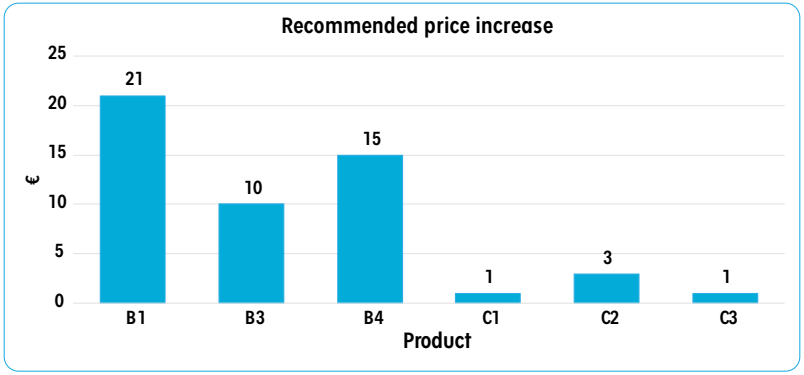
• The simple average of the ROI values and the effect of the capital structure on the enterprise ROI are presented in separate frames

• The average deviation characterizes the variability of ROI values - their average distance from the simple average

Specific data

Characterize the fictitious firm in the first PPROI calculations. However, the variability of ROI values tends to be greater than in the report, since in traditionally managed enterprises there is only distorted information on product costs, ROI values for products are generated randomly.

Pricing Products According to Target ROI



Product	Costs	Capital Employed	Target ROI	Target price	Target profit	Real price	Target price increase
	€	€Year	€/€Year *100	€	€	€	€
A1	225.32	54.78	8	230	4.68	230	
A2	214.44	52.13	8	219	4.56	220	
A3	198.17	53.56	8	202	3.83	202	
A4	258.16	57	8	263	4.84	265	
B1	149.88	186.15	8	165	15.12	144	21
B3	148.32	165.89	8	162	13.68	152	10
B4	161.56	172.33	8	175	13.44	160	15
C1	50.1	27.56	8	52	1.9	51	1
C2	48.12	26.11	8	50	1.88	47	3
C3	56.33	21.22	8	58	1.67	57	1

Costs, capital employed and ROI in product pricing

ROI integrates price, costs and capital employed in a logical and mathematical order. The difference between price and costs, i.e. the profit as effect of the processes for the product, is contained in the numerator, the capital employed in the denominator of the ratio. When information on costs and capital employed in the processes by products exists, then the logically calculated price of the product follows from a modification of the equation

ROI = (Price – Costs) / Capital employed ⟶ Price = Costs + Capital employed * ROI

If there is to be no mutual advantage or disadvantage between products, the ROI value in pricing should be uniform for all products. And the desired level of ROI must be decided by the top management of the enterprise. Fluctuations in the actual price around the target value are permissible, but should be justified.

In traditional calculations of product prices by percentage mark-ups on costs, the process demands on capital employed are ignored, thus negating elementary financial logic and creating a series of intractable contradictions. Moreover, information on product costs is distorted, so that there is no objective information support for pricing and price negotiations. The chaotic situation is exemplified by the various pricing models requested by some corporations not only of their enterprises but also of their suppliers. Each of these models leads to different result, and all are based on overhead surcharges to product costs.

The costs and capital employed calculations in PPROI characterize the financial requirements of products on specific resources, which is a basic assumption for the correctness of the calculated values.

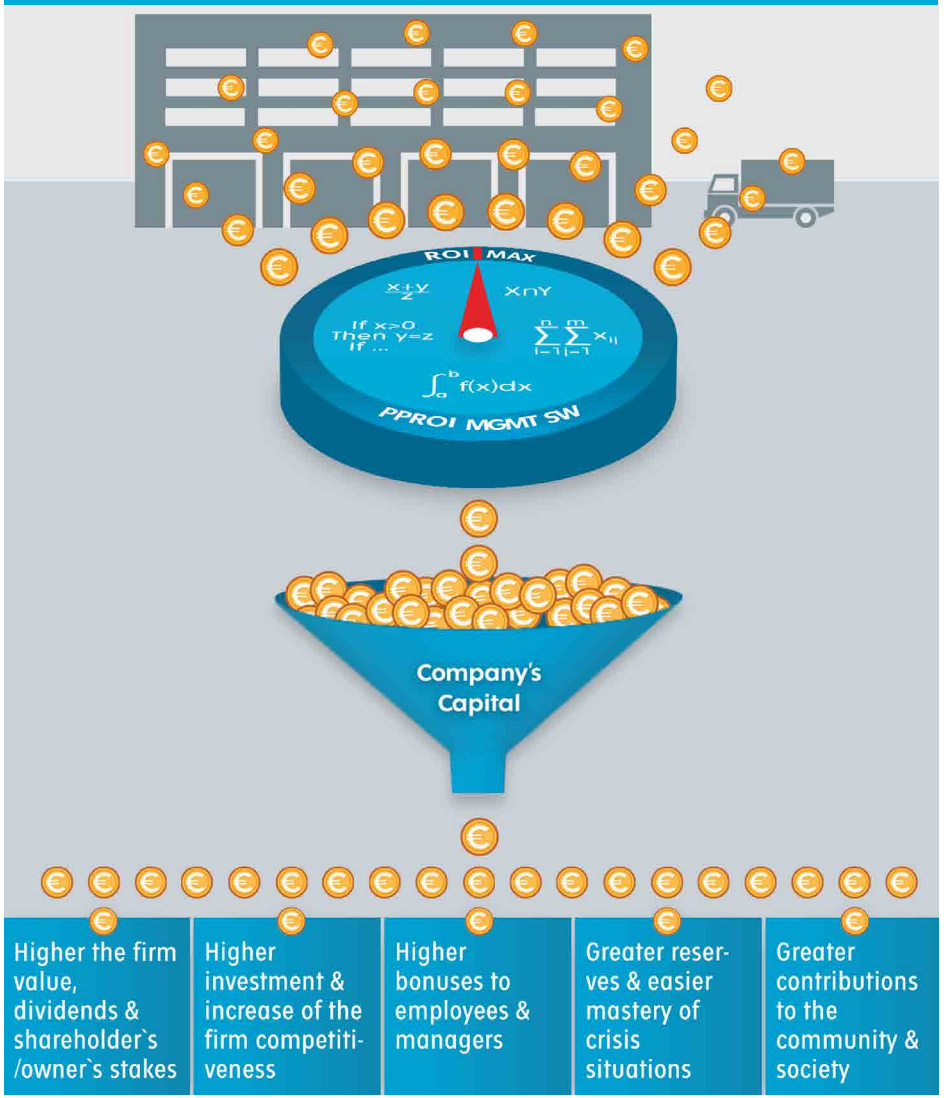
Data in the table, listed by product number, refer to the same products as in the previous report to senior management. Costs and capital employed are, however defined for product units. Prices are calculated by PPROI at an 8% ROI target and corresponding profits for each product. Following the information on actual prices, the required price increases for products whose actual ROI is less than 8% are indicated. This increase is also displayed in the graph.

Continuous efforts to reduce capital wastage in costs and capital employed for products, while respecting the trade-off of both variables

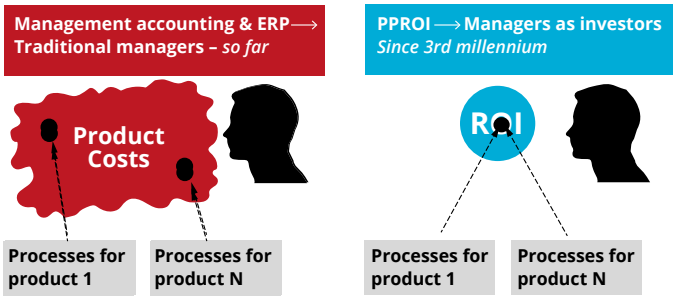
Conceptual change in product pricing is a necessary condition for rational management of the whole enterprise, but it does not imply a reduction in efforts to use the enterprise's resources most efficiently. On the contrary: The resource requirements of products and their processes need to be assessed not only in terms of costs but also in terms of capital employed, and PPROI makes this possible. In a number of important contexts, lower-cost alternatives are associated with higher requirements on capital employed. For automation and robotics in manufacturing, this is predominantly true.

Far-reaching Benefits of Enterprise Management According to ROI Criterion

PPROI – End of capital wasting due to information systems weaknesses



Revolution in the financial thinking and focus of managers



The fundamental change is a change in the financial mindset of managers focused on product costs. Moreover, these are calculated very inaccurately - their values are vague. Even with correct cost calculations, this is only one factor of ROI. Capital employed in processes is a reason why lower cost situations can be disadvantageous in terms of ROI. From optimization theory and practice, the dependence of the evaluation of alternatives on the criterion used is well known: „What criterion, such evaluation, decision, and results". The dire situation in the financial information on products and their processes prior to PPROI is characterized by the commentary on each variable in red font. The synthetic criterion, ROI, and capital employed are completely absent,, and the other two variables are flawed. There is nothing right.

$$\text{ROI} = \frac{\overset{\text{Wrong pricing formula}}{\overset{\text{Unknown}}{\text{Price}}} - \overset{\text{Distorted}}{\text{Costs}}}{\underset{\text{Unknown}}{\text{Capital Employed}}}$$

In PPROI all these problems are solved.

Financial implications of changes in crucial management information

By completely ignoring ROI, all kinds of product and process evaluation and subsequent management can be fundamentally flawed. The actual ROI is therefore significantly lower than the achievable one. Managers are thus massively, albeit unwittingly, wasting enterprise capital and thus natural resources. Not only the enterprises and their stakeholders suffer, but the whole of society, which depends on the enterprises results.

The PPROI, as stated in the previous pages, contains all the variables of the above basic equation and their correct values. The previous huge wastage of capital due to fundamental weaknesses in the available information is not necessary. Everyone can benefit.

This requires a rethinking of the basic postulates of traditional management theory, but such changes are common in scientific breakthroughs. The absence of key financial information and incorrect product costing must also be dealt with by ERP. Using the existence of PPROI is the best solution.

Commentary by Authors of PPROI Content and Math Attributes

Dear reader,

We were once asked to say, in a few words, „in what aspect is PPROI the most groundbreaking?“. After a short thought, we answered: ***„The application of a definite integral“***. This step introduces into enterprise management, and economics in general, an entirely new type of variable which uses a two-dimensional measurement, in moneytime (MT) and quantitytime (QT) units of measure. Without this, it‘ s impossible to manage the enterprise towards its natural financial objective, i.e., the maximum ROI value, and to solve other chronic problems of enterprise management. The photo documents the clarification of the application of a definite integral by Prof. Milan Matějka at a conference dedicated to PPROI in the lecture hall of The Academy of Sciences of the Czech Republic. A detailed explanation was a prompt response to the conference participants‘ request in the final discussion because for all of them, it was a completely new thing.

The launch of PPROI development was preceded by a close link of the academic and practical activities of a team of experts with a complementary knowledge backgraound. Within the Executive Development Programs – „EDP“ of the Prague University of Economics and Business the training of top executives of companies in progressive management methods took place. At the same time, these methods were implemented in the restructuring of some industrial enterprises by the consulting firm Central European Productivity Center – „CEPC“. Prof. Matějka headed both EDP and CEPC. The restructuring of companies was focused on the introduction of lean manufacturing, teamwork, and the overall optimization of enterprise processes under the ROI criterion. The top executives of the restructured companies had previously completed EDP and were thus theoretically prepared for fundamental changes.

However, we faced the problem with ERP information system used in all companies, albeit from different providers. The basic conceptual elements of ERP in production management reflect the procedures of „scientific management“ from the first decades of the 20th century. The computerized enterprise information systems of the 1950“s took over these methods as unquestionable and enabled automatic data processing. However, this has conserved oversimplified information procedures, designed moreover for the organization of production, which has gradually become obsolete. This also applies to the MRP plan developed in the 1960“s, which in itself is oversimplified and unfeasible. In terms of content, the most striking weakness of ERP is the lack of information about machines and equipment in processes, as they currently generate a wide range of cost components and, together with buildings, represent fixed capital. This is another of the basic reasons why the management of enterprise product, processes, and resources to maximize ROI is impossible.

Creating a system of physical and financial information necessary for the management of newly introduced practices via Excel and later Access, which we tried, led to provisional and unsatisfactory solutions. Therefore, in cooperation with IT programmers, we started developing fully-fledged software, with its own database, computing, and user layers.

The basis of PPROI are completely new solutions to enterprise management issues from the content and mathematics point of view. PPROI is associated with the reassessment of a number of postulates and models of traditional management theory from the ground up. The application of PPROI has therefore encountered a lack of understanding of its procedures by traditionally educated managers.

To address this knowledge problem, some academics and practitioners recommended us to first thoroughly explain the characteristics of PPROI from a theoretical perspective in the form of a newly conceived enterprise management textbook. And to do so in conjunction with the PPROI software in its tutorial form, which demonstrates the application of new theory in a real system that students can operate to gain practical knowledge. We accepted these recommendations as meaningful, also because it is impossible to give examples of very complex calculations of financial parameters of individual products outside sophisticated software. That is why we have developed a demo version of PPROI.

The text of this document has the function of a theoretical explanation and justification of PPROI procedures and can be seen as a textbook, albeit in a very unconventional form. While striving for maximum density, we also strive for clarity and concreteness in our claims.

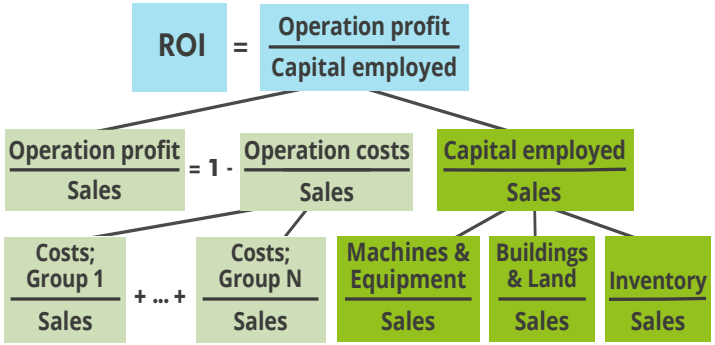
Prof. Ing. Milan Matějka, DrSc.
Ing. Marcel Matějka, PhD

Conflict of Management Accounting with Financial Accounting and Its Solving in PPROI

Where is the root cause of focusing on costs and ignoring ROI in enterprise product and process management?

The natural objective of any business is to strive for maximum return on investment. This is a basic law of economics given by nature, interest of investors, and driver of economic development of the society. Respect for this law is a fundamental requirement of scientific management. In the enterprise, as organizational unit of business, ROI is a rate of reproduction of its capital, i.e, the very essence of the enterprise. ROI maximizing should be continuous and achieved through processes by products, each aimed at ROI MAX. This raises the fundamental question: Why does enterprise managers ignore ROI in the product and process management, and why is this so in enterprise information systems? We explained this from a math viewpoint - the need to apply a definite integral. But there is also a content reason. In 1911, the lawyer Louis Brandeis, the author of the term „scientific management," linked it to costs. Thus, under the heading of science, a huge fallacy arose - ignoring capital and ROI. This lasts until now, even the current managers financially think only on costs.

ROI as the top variable in the pyramid of financial ratios



The synthetic property of ROI, its superiority to all other financial variables, is graphically visible from the pyramids of financial ratios, characterized by the diagram on the left. It makes clear that management theory and practice completely ignores ROI, capital employed and its specific components in ratios shaded in blue and green in the diagram. The first version of the pyramid was sketched by Donaldson Brown already in 1912, thus in fact contradicting the thesis of Louis Brandeis.

In practice, the pyramid is rarely used because it contains past enterprise-wide data. It does not provide information on processes generating products, and is not useful for the planned enterprise management. However, this does not change the content and key importance of the ROI itself. Buildings, machines, other equipment and inventories represent a visible, physical form of capital employed, to whose monetary values should correspond the financial effect, profit. If enterprise A has five times the capital of enterprise B, it should also have five times the profit. Profit-to-sales ratios can be quite different and to evaluate enterprises by them is generally misleading. However, the same applies to products and their processes.

Finanční účetnictví, manažerské účetnictví, ERP a PPROI

The contradiction between D. Brown and L. Brandeis in fact exists also in the contradiction between financial and management accounting. Financial accounting records costs and capital - in the income statement and balance sheet, but only for the whole enterprise and standard time periods. Capital is recorded at period boundary points. Financial accounting has no information and no influence on processes and their products. It only states their aggregate consequences afterwards. Management accounting focuses on products and partly on their processes, but it does not contain any information on capital employed; cost information is partial and total cost calculations are distorted.

In the standard enterprise information systems, direct material costs are recorded by BOM and direct labor costs according to processing time of operations, the number of operators in the operations and the wage rates of the work centers. The inclusion of financial accounting into ERP has only put two different groups of information under one umbrella.

	Information System	Capital Employed and ROI	Products and their Processes	Accuracy of Calculations	Management Information
ERP	Financial accounting	YES	NO	YES	NO
ERP	Management accounting	NO	YES–Costs	NO	Yes, partial, misleading
	PPROI	YES	YES	YES	YES, comprehensive, correct

PPROI provides comprehensive information on costs, capital employed and ROI in processes by product, and its correct application ensures the best financial results of the enterprise's activities, which are later reflected in aggregate values of the financial accounting.

Application of the Definite Integral in Economic Measurement on a Universal Scale

Removing a key weakness in enterprise information systems, management theory and practice

To the uninitiated reader, it may seem incredible that there is no information in ERP, and in management theory and practice, about capital employed in specific enterprise processes. Anyone in any industrial enterprise can see the operation of machining a particular part of a product. The value of the machine and the part of the product itself are two of many components of capital employed to which the financial return - profit - should correspond. It has already been stated in the introductory Executive Summary that the mathematical solution to the problem lies in the application of a definite integral when measuring it in moneytime units. Since classification of economic variables does not take this mathematical type of variable into account at all, we now devote separate attention to it.

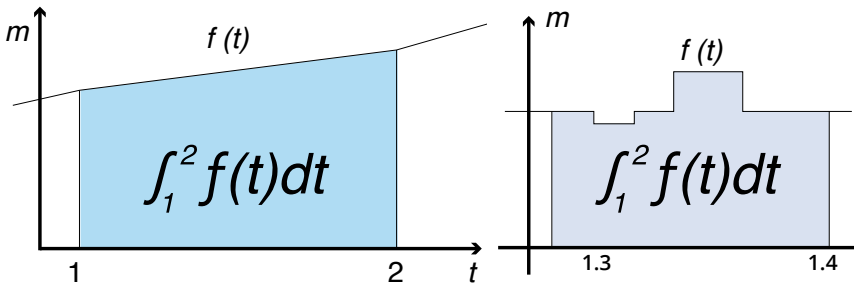
Formula of a definite integral, its application in enterprise processes and in banks

$\int_a^b f(x)dx$ A definite integral is generally defined as the area under the function y = f (x) and over the x-axis from point a to point b on that axis. In standard examples a function has the character of a continuous curve, but it needn't be. It may be a straight line that is constant, or increasing, or decreasing, or it may be a successive combination of these variants and their values may change in leaps and bounds. The variable on the y-axis can be money – m, the variable on the x-axis can be time – t, its boundary points a, b can be denoted as moments 1, 2 and a definite integral written as

$\int_1^2 f(t)dt$

When measuring capital employed in enterprise processes

- the variable on the x-axis is process time, points 1 and 2 are the start and end points of a particular process phase, either processing or logistics
- the variable on the y-axis is the monetary value of a physical item, e.g. a part of a product.



Date	Stock	Stock from 1.3. to the date	
	€	€Day	€Year
1. 3.	5000		
4. 3.	4300	15000	41.10
10. 3.	5100	40800	111.78
15. 3.	6700	61200	167.67
22. 3.	5200	114800	314.52
1. 4.	5200	166800	456.99

- the variable characterizing the capital employed by a definite integral is two-dimensional, expressed in money-time units.

The units of time and money may differ and their choice determines the units of measure of the capital employed, e.g. €, Year ⟶ €Year.

The second chart and table characterize the continuous cash balances in a particular bank account during the month of March. Area of the definite integral from the start of March 1, to the start of April 1, calculated by measuring time in calendar days, is converted to time expressed in calendar years. The account holder receives a yield on the integral balances in the period at the interest rate set by the bank. E.g., if the interest rate € / € Year = 0.05, then yield = 456.99 * 0.05 = € 22.85.

Unlike the interest rate in a bank the ROI of enterprise processes according to products is not a priori given. But the basic assumption for its calculation, i.e. the measurement of capital employed by a definite integral, is available.

Application of the definite integral as an example of major trends in current science

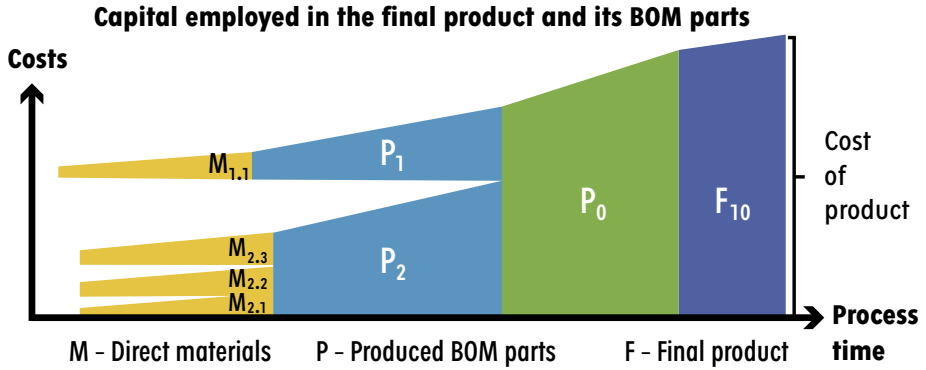
Experts have identified two main trends of science on the threshold of 3rd Millennium: (1) Disappearing boundaries between disciplines; (2) The dissemination of the apparatus of mathematics that was previously regarded as useless in some disciplines.

The application of the definite integral is a striking case of these two trends in linkage. Not only does the barrier between measuring the balance of money in a particular bank account and the capital employed in the processes of an industrial enterprise disappear. The application of a definite integral in the sphere of logistics is also indispensable. Just think of the huge capital employed in containers at ports, in rail and road transport. It cannot be measured without a definite integral. A definite integral is indispensable type of economic quantity in general.

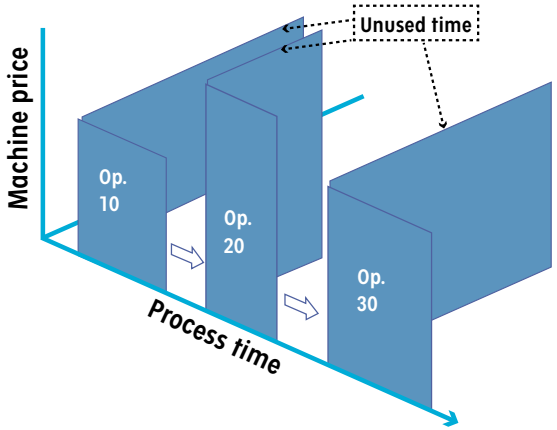
Definite Integrals of Types of Capital Employed

Capital employed in the final product and its BOM parts

Diagram right illustrates the process times from the purchase of materials through their storage, manufacturing of individual parts and storage of the final product until the moment of its sale. On the y-axis is the capital value in inventories. The initial value of materials is their acquisition price. The stocks increase with the growth of process costs. The areas are expressed in money-time units.
The product's costs are identical to the capital employed in the product at the time of its sale. If the enterprise buys parts P_1, P_2 as materials, capital employed in his manufacturing the final product F_{10} is much lower, but product costs are likely to be higher.



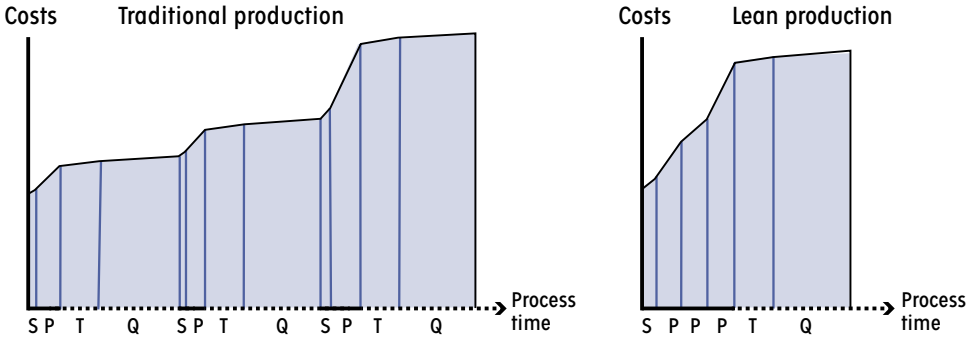
Capital employed in machinery



Capital in inventories is currently only a minor part of capital employed. The bulk of it is fixed capital in buildings, plant and equipment. And capital in processing machinery, handling robots and other equipment is growing steadily.
The basis for the calculation of capital employed in processing machines is information on machine times in processing operations on individual BOM parts. These times have to be increased in proportion to the times of the machines concerned in idle times. Calculations of time utilization of individual machines over all manufactured parts and the increase of values in active times by values in inactive times is done automatically by PPROI for the product portfolio in the plan. It does the same for depreciation calculations.
PPROI captures all capital employed in the process phases related to the BOM parts for the final product and in the process phase on final product itself, as shown in the figure above. On these phases, PPROI adequately allocates the capital employed in the indirect territories of the enterprise. All the capital of the enterprise in the plan period is assigned to specific products.

Inventory in traditional and lean manufacturing

Very important is implementing lean manufacturing, developed at Toyota. Compared to traditional production in isolated work centers, this better utilizes the operators and reduces labor costs in the processing operations. Striking is the reduction of logistics costs and capital employed in inventories of produced parts (see right figure). Among line-connected work centers, stock of produced parts disappear in front of machines (S), in transports (T), and in queues (Q). But fixed capital in machines can increase. PPROI contains all information for both production types.



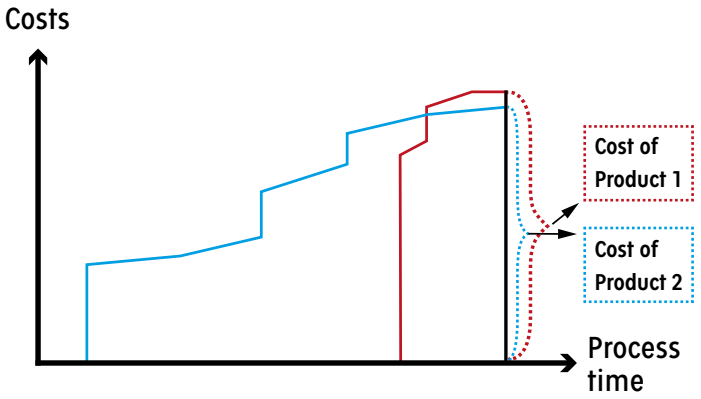
Revealing the Math Attributes of Product Costs – Countering their Misuse

The general necessity of describing the properties of variables from a mathematical point of view

The application of a definite integral in financial measurement means the introduction of a key variable that did not exist before and whose mathematical properties need to be understood. However, from a mathematical point of view, existing variables also need to be described. If this is not done, there is a risk of misinterpretation and misuse. The objective function of each variable must also be consistently respected. Otherwise, this is a misuse of mathematics, which is unfortunately common in the economic field. This also applies to the product costs.

To our knowledge, product costs have never been defined mathematically in the literature. We consider this to be the fundamental cause of their misunderstanding and misapplication. Yet the mathematical definition of this variable is clear and its properties are obvious from its graphical representation.

Cost of a product as a value defined at a certain point in time



The development of costs in processes for a particular product is characterized by an increasing function. The figure on the left outlines the evolution of costs for two products, each containing only one manufactured BOM part and involving purchased materials at the beginning and during the processes. These financial inputs are expressed by the vertical lines. The linearly increasing line segments simplistically characterize the different growth rates of the product costs in the different phases of production and in the storage of the finished product. The cost of each product is defined as the value of the function at the end of the process, when the product is sold. This definition is of fundamental importance, since expecting a return on any monetary value at a particular point in time is fundamentally nonsense.

The areas under both functions are definite integrals of the capital employed in the inventories of the respective products from the start of the production until the moment of shipment. This capital is considerably larger in the case of product 2, although its costs are lower than those of product 1. If the fixed capital in processes for both products is proportional to the scope of these processes, then the profit for product 2 should be substantially higher than the profit for product 1. The illogic of determining a return proportional to the product's costs can be compared to a situation in which the bank would determine interest on the client's account balances at the time of calculation, regardless of the balances at other points in the period for which interest is calculated.

Inter-enterprise intersections

It is clear from the diagram that a substantial part of the product costs are direct material costs. These are the transferred prices of the suppliers' products. These prices include the suppliers' profits by which they increase the costs of their products. Thus, there is duplication in the calculation of profits. The profit for the same item is calculated first by the supplier and and then by the buying enterprise from the transferred value from the supplier, without having anything to do with the processes within the enterprise and their resource requirements. The greater the proportion of these transfers, the greater the duplications. There is no inter-enterprise intersection in the calculation of profits proportional to capital employed within ROI.

Respecting the function of costs

The objective function of costs is clearly given in the ROI equation. The costs in the ROI numerator together with the product prices determine the profit of processes for a particular product. There can be no doubt about the fundamental importance of costs and the need for their correct calculation. On the other hand, it is unacceptable to substitute capital employed in the denominator of the ROI by costs. Then it is no longer ROI but a profit-to-cost ratio with the characteristics criticized above: return on value defined at a point in time and return from inter-enterprise duplications. But as long as there was no measure of capital employed - a definite integral has not been applied, this absurd situation had no solution.

Enterprise ROI as a Weighted Average of ROI of Processes by Products

Processes by products as in-house investment areas; Manager as investor

Processes of industrial enterprises are traditionally described, planned and overall managed according to products. This makes sense, as these processes often differ fundamentally in content and scope; they involve different processing operations, different resource structures within operations, and other different physical attributes. The prices of products and used resources also differ. Therefore, the ROI values in the processes for individual products also differ. The enterprise ROI value is a weighted arithmetic average of the ROI values in the processes defined for individual products, where the weights are the values of capital employed (further we use the abbreviation CE) in particular processes. CE for a certain product is determined by CE for a unit of the product and by quantity of the product. The average can be expressed through shares of CE in processes by products.

$$ROIe = \frac{\sum_{i=1}^{n} ROIi * CEi}{\sum_{i=1}^{n} CEi} = \sum_{i=1}^{n} ROIi * \frac{CEi}{CEe}$$

where

ROIe	is ROI of an enterprise
ROIi	is ROI of processes for the i-th product
CEe	is Capital Employed in the enterprise
CEi	is CE in processes for the i-th product

In order to maximize the enterprise ROI, it is necessary to strive for maximum ROI in the processes for individual products and structuring CE in favor of products with above-average ROI values. So, the processes defined for individual products should be treated as in-house investment areas. Such thinking and acting of an enterprise manager are identical to the thinking of an investor who always strives for the maximum return on the entire portfolio of invested capital and the manager should think and act like an investor.

Processes	ROI	CE Share	ROI * CE Share
Product A	0.05	0.20	0.01
Product B	0.075	0.80	0.06
Enterprise	**0.070**	1	

Processes	ROI	CE Share	ROI * CE Share
Product A	0.05	0.80	0.04
Product B	0.075	0.20	0.015
Enterprise	**0.055**	1	

Tables left illustrate the impact of CE structure on enterprise ROI. With the same ROI values in the processes for the individual products in both tables, the enterprise ROI value is significantly higher in the first table because there is much higher CE share in the processes for product B, which have a higher ROI value than the processes for product A.

Dependence of ROI in processes for a specific product on the portfolio of all products in the assessed period

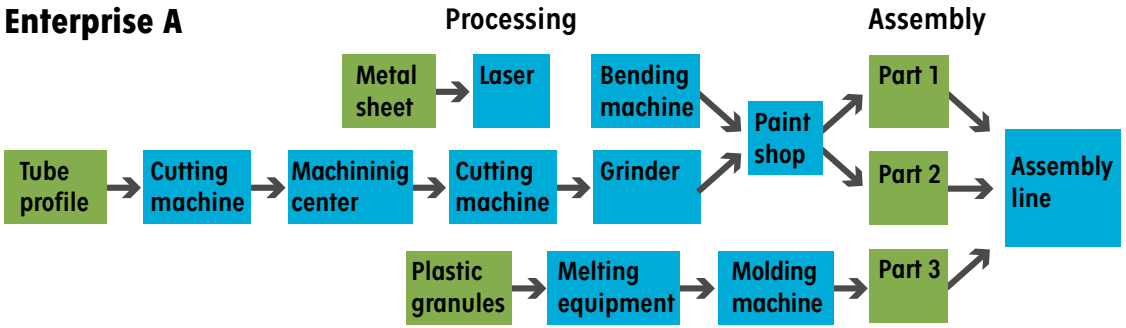
As a significant part of the costs and a crucial part of the capital employed are fixed, the total costs, capital employed and ROI in the processes for a unit of measure of a certain product depend on the quantity of all products in the planning (or previous) period.
The time utilization of a particular machine depends on the time requirements of all operations for all parts produced in a period. As these demands increase, the proportion of time in which the machine is idle decreases, thus decreasing the fixed costs and the capital employed for each operation.

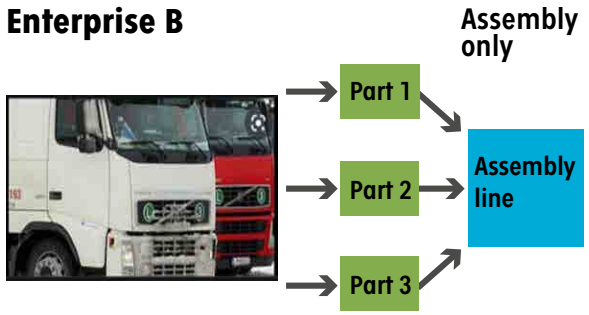
The fixed costs and capital employed, defined for the individual territories of the enterprise, allocated to the objects in phases of the direct processes, depend on the number these objects. The greater their quantity, the lower the allocated values per object and the lower the total costs and capital employed per unit of each product, and the ROI value per unit of product increases.
In PPROI, the dependence of costs, capital employed and ROI in the processes for individual products on the quantity of all products in the plan, is reflected by dynamic calculations.

Capital Employed and Costs of Products from the Supply Chain Perspective

Alternatives for the manufacturing products within an enterprise, different in process scope

If someone did not fully understand from the previous explanation what is capital employed in the processes for a certain product, he/she will surely understand from the following pictures. The first diagram characterizes the manufacturing processes of a particular product in an enterprise A from basic materials. The operations at the machine work centers produce parts 1,2,3, which are assembled to the final product. The second diagram characterizes the manufacturing of the same product in enterprise B, limited to the assembly of purchased parts 1,2,3. There is extra capital employed in processing machinery and equipment in enterprise A compared to enterprise B. This is probably many times greater than the capital employed in the assembly line. Only a laser can be more expensive than an assembly line. The space requirements of production and work-in-process inventories are also significantly bigger in enterprise A.





Information on capital employed and costs in ERP and PPROI

ERP

As has been said repeatedly, there is no information on the capital employed in processes for the products in ERP and hence its huge differences in enterprises A, B are ignored; managers are financially blind. And product costing is distorted. The basic decision „Make or Buy" is not possible. Similarly, it is not possible to correctly financially evaluate different products within a given enterprise, since each one has different requirements for capital employed.

PPROI

As described in the tables on page 1.3, the PPROI calculates both comprehensive costs and capital employed for each product in the plan's product portfolio. From these values and the target ROI value, it calculates the price (see the price report on page 1.6.) When deciding on process alternatives for the same product, the user should prefer the solution that has a lower price, which is important for product salability. In the example, the production in enterprise A is more efficient, despite the capital employed is four times higher than in enterprise B.

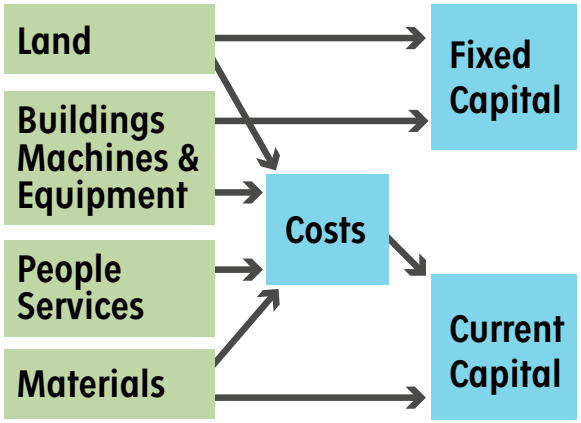
Enterprise	Capital employed €/€	Costs €	ROI target €/€Year	Price €
A	120	180	0.1	192
B	30	198	0.1	201

Economic and environmental aspects of supply chains

Growing inter-enterprise breakdown of the manufacturing of a particular product between different enterprises increases its costs in the finalizing enterprise, due to the profits of suppliers and transport and other logistics costs. Therefore, the costs in enterprise B are higher than in enterprise A. Excessive inter-enterprise fragmentation of production has also negative environmental consequences and increasing fragility of the supply chain. The wider scope of manufacturing of the product within a certain enterprise is advantageous as it enables broader continuous processing flows and wider use of lean production. In our example, production in enterprise A versus enterprise B saves inter-enterprise transport of parts 1,2,3. Transports from the producers of basic materials - metal sheets, tube profiles and plastic granules are necessary in both alternatives; they differ only in the distances to the purchasing enterprises. However, not everything is possible and efficient to produce within one enterprise.. In order to determine the optimal scope of production of individual products within the enterprise, financial calculations of costs and capital employed are necessary.

Effects of Resource Structure on Capital Employed and Costs; Robotization?

Main types of resources and their impact on costs and components of capital employed



Costs and capital employed are generated by specific resources. However, the impact of each resource component on total costs and capital employed varies. We explained on the previous page that as the proportion of purchased materials increases, costs of products generally increase, but capital employed decreases. But even within the same scope of processes for a given product, different resource structure can have opposing effects on costs and capital employed. This is apparent from the diagram of the relationships of the main types of resources to the costs and capital employed components.

Regarding capital employed
- Land, buildings, machinery and other equipment are reflected in fixed capital, which usually forms the majority of total capital employed
- People and services are reflected in current capital through costs; these resources do not themselves constitute capital employed
- Purchased materials, whether direct or indirect, that are in inventories represent current capital. In addition, like other resources, they are reflected in current capital through costs in inventories of work in process, semi-finished and finished products.

People versus machines

The most characteristic feature of development since the Industrial Revolution is the growth in the quantity and value of machines and equipment, which to some extent replace people. The capital employed in enterprises grows and the profits of enterprises should grow proportionately. When human labor is substituted by machines, costs should fall so as to increase profits corresponding to the required ROI and the price of the machine in question.
In particular, it must be considered that while the labor costs of processing operations are variable, the capital employed is fixed, which is also true for depreciation, whose weight in process costs is mostly growing. The time utilization of the equipment is therefore of fundamental importance, as it varies. Its impact can only be objectively quantified through data in an information system that records the capital employed and is able to correctly determine the costs generated by the machines, while respecting their variable and fixed components.
Standard calculations of investment efficiency through IRR or NPV are methodologically transparent, but they are based on assumptions that are not fulfilled in practice, already for the first year of the machine's functionality.

ROI of robotization

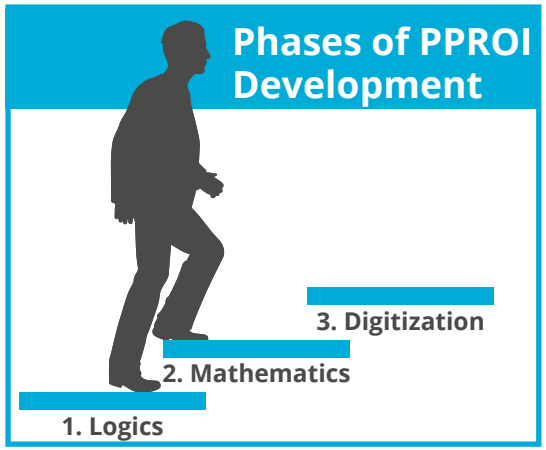
The problem of robotic efficiency, together with the supply chain problem, are among the hottest issues of our time. In order to make it as concrete as possible, we will use the example of lean manufacturing from the book „Kanban; Just-in-Time at Toyota". This was published in 1985 but is still very relevant today. A single operator operates 9 machines in line, working at takt time 113 sec. He removes parts from individual machines after their automatic processing and inserts new ones. This operator would need to be replaced by 9 handling robots, which on average would be used less than 10% of the takt time. At the high robots' prices, there would be high depreciation, reflecting unused times of robots.

To this must be added costs of energy, maintenance and technical support of robots which is not recorded in direct processing costs, but the wages paid to the relevant technicians for robot-related activities are certainly not negligible. The total costs have to be calculated very carefully and increased by profit corresponding to the capital employed in all the robots which is half of their purchase price. (Half of the purchase price is the average value of the robot over its lifetime).
It is always necessary to ensure that robotization saves not only the work of operators, but also their number, i.e. it does not lead to lower time utilization of operators.
In PPROI, the individual robots and their time in processing operations are recorded separately, just like other equipment, and the costs and capital employed are calculated for them as well, entering the ROI of the individual products and the entire enterprise.

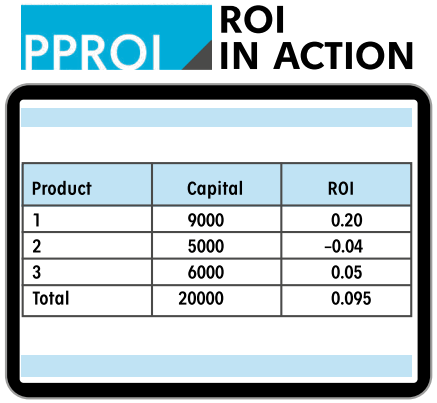
Finalizing Current Science into Software, Teaching Enterprise Management via PPROI Demo

Phases of PPROI development

The basis of science is understanding and respecting the laws of nature. This is true in general. If the laws of physics are not respected, any solutions are not workable. If the laws of economics are not respected, many different physical solutions can be implemented, but they generate avoidable financial losses. The creation of the PPROI was therefore based on the formulation of the natural objective of any business, maximizing ROI, which is in fact a basic law of economics. The whole logic of PPROI development followed on this.
The next phase, typical for science in general, was the expression of verbally defined concepts and their basic relations by means of mathematics. Both the capital employed in the processes and the product costs were defined mathematically. The most challenging part of PPROI development was the logical and subsequently math definition of the elementary variables and their relationships so that together they result in the ROI of the enterprise.
In the third phase, the system of mathematical variables was translated into the language of current IT. This is the hallmark of contemporary science. Without this, the mathematical calculations of PPROI would be untenably demanding and not feasible in the time required. The result is a logically and mathematically reasoned software that behaves like an enterprise itself and enables flexible management of the enterprise to its natural objective.



Versatile implications of revolutionary changes in enterprise financial management



The groundbreaking logical and mathematical solutions of PPROI are multifaceted and need to be reflected in practice, information systems and theory.
• If investors find that there is an opportunity to manage the enterprise's products, processes and resources, and thus the enterprise as a whole, to maximize the return on their investment - which is evident from the data in the tablet image on the left - they will ask managers to do so
• Managers under pressure from investors will demand appropriate information from enterprise information systems, especially ERP
• ERP developers will demand guidance from management theory
Management accounting can no longer persist in a one-sided focus on costs and calculate them in a fundamentally flawed way. Ignoring the capital employed in processes, its turnover time and the resulting ROI of processes by product is indefensible, as well as the product costing through overhead surcharges. Even enterprise management cannot ignore science indefinitely, especially not in the 3rd millennium.
Not everything in traditional enterprise management is wrong. Some practices in physical process management, e.g. non-investment-based reduction of process times, or reduction of process defects by continuous improvement, are right and belong to the elementary factors of increasing the enterprise's ROI. But they should also be automatically reflected in the ROI value in the information system.

Education of managers through PPROI demo

The perception of the enterprise as a controlled reproducing organism, whose comprehensive measure of reproduction is ROI, should be the basis of management thinking. And since the PPROI software is so far the only tool that enables comprehensive management of the enterprise according to ROI, we have developed its demonstration version for educational purposes. This relates to a fictitious enterprise and is filled with input data that can be changed. The software should be used already for teaching in management schools, for several reasons.

1. Correct calculations of ROI values from the entered data outside sophisticated software are impossible due to the complexity of the calculations
2. Students get to know the functionality of real software. At the same time they will get an idea of the interdependence of enterprise parameters
3. Such a form of teaching corresponds to the current IT era and young people will accept it as a matter of course
However, the PPROI demo version is also available for on-the-job training of managers.