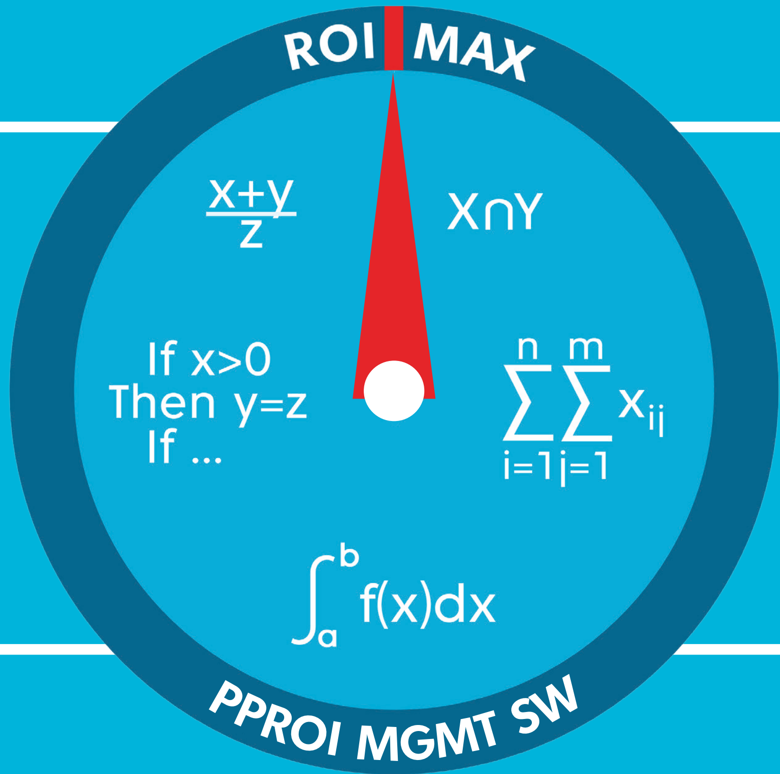
MODERN SCIENTIFIC ENTERPRISE MANAGEMENT
to Maximum Efficiency

by

PPROI

Aligning
Products, Processes and Resources
to Maximize ROI



GROUNDBREAKING MANAGEMENT SOFTWARE

T A Č R

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Foreword

Dear reader,

In this PPROI presentation document, we will try to clarify the truth of the statements made on the title page. PPROI contains a spectrum of breakthrough information, justified in terms of science and through the procedures and tools of contemporary science navigates enterprise management to maximum business efficiency.

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, which, in addition to traditional one-dimensional variables, form the second pillar of correct managing any business. We are sure that the application of a definite integral will become the timeless standard, because only under this assumption it is possible to manage an enterprise to its natural financial goal 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 background. 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 of how to manage the new practices with an information system. We were aware that traditional information systems, now called Enterprise Resource Planning, abbreviated to ERP, could not help us much. Their basic conceptual elements 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 employed 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, which we tried, led to provisional and unsatisfactory solutions. The Access application also proved to be an unsustainable provision for a long time period. Therefore, in cooperation with IT programmers, we started developing fully-fledged control 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 therefore associated with the reassessment of a number of postulates and models of traditional management theory from the ground up. However, we also consider the corresponding advanced control SW to be irreplaceable, because only through it is it possible to express the interrelationships of many partial variables characterizing enterprise products, processes and resources projected into a complex variable, ROI of the enterprise, and perform very demanding calculations. We think that such SW should be a tool of modern education of managers and for these purposes we have developed a demo version of PPROI. Individual aspects of the matter are described on the following pages of this document. Hoping that text is intelligible we look forward to your response.

Marcel Matějka, Milan Matějka

Structure of the Document

The way of presenting the issue

The document is divided into four parts which are characterized below. Each page has a specific content that is listed in its header. The references to other pages are limited. We try to make our standpoints to the problems and their solutions dense and at the same time presented as unambiguously as possible. That's why we use math tools.

Part 0. Why New Management Software is a Must / Why PPROI

The task of this part is clarification of the essential chronic problems of traditional enterprise management, which non-solution generate a huge waste of capital and thus natural resources, which are still more limited. The solution to this problem is therefore urgent.
The basis of solution is the perception of the enterprise as a controlled organism with a clear natural mission, which should be respected in all contexts of enterprise management. This mission is identical with the objective of any business: the maximization of ROI, which should be interpreted as a rate of capital reproduction.
Achieving this objective at the enterprise level is possible only by such oriented management of products, processes and resources. This requires information on capital employed and ROI in processes by product which did not exist before PPROI. So we explain the problem-solving from scratch. It has mathematical aspects. The measurement of capital employed and ROI requires the application of a definite integral. From a math point of view, it is necessary to clarify the attributes of costs and refute seemingly self-evident management of products and their processes according to costs, as it denies the basic financial principle. The same goes for traditional product pricing. All this is explained also from the from a supply chain perspective.
The financial variables should be seen as a function of physical resources. At the same time, it is necessary to be aware of many physical alternatives and the need to choose those that lead to ROI maximum. The values of financial variables must be defined for specific resources; it must end, inter alia, simplistic calculations of products costs through overheads.
This is just a minimum of requirements for enterprise management to enter the field of science and to end the groping of managers with huge capital waste. However, these requirements can be met only through a conceptually new information system in the form of computer software that automatically processes a large amount of interconnected data and present results while faithfully simulates the behavior of the enterprise itself. The demonstration version of such a system should serve to innovatory education in enterprise management, appropriate to our time. That's why we prepared the PPROI Demo. It is presented on the last page of this section.

Part 1. PPROI Development and Applications / PPROI Devel.

The enterprise information systems that form the core of today's ERPs have arisen in a large number in the early 1970s, according to Joseph Orlicki algorithm to create a plan of the starts production of BOM parts and order direct materials in the long outlook. This computer-generated plan, called Material Requirement Planning, abbreviation MRP, followed on previous methods of describing production processes. PPROI, compared to ERP, has the original system architecture, many times more complex computational algorithms and no counterpart. We therefore assume that some readers may be interested in the very basics of the system, its development and applications. Therefore, we comment on this in a separate part of the document.

Part 2. Brand New System of Financial Information / Financial

This part deals in detail with financial variables and their values from content and math points of view. The first page presents the properties of these variables on the enterprise level, most other pages are devoted to the description of procedures for calculating the capital employed and costs generated by individual resources in processes according to products not only in the phases of processing operations, but also in the phases of logistics processes; these procedures are applicable to the financial parameterization of processes in purely logistics companies. Separate attention is paid to calculating the impact of defects in processing operations on material, labor and machinery costs, while distinguishing between repairable and irreparable defects. The records of capital employed and costs in indirect territories and their allocation on the phases of direct processes are also described separately. Two pages deal with product pricing.
Then, the behavior of financial variables in different types of strategic decision-making and the irreplaceability of ROI are described. This part is closed by a case study.

Part 3. New Physical Variables in Enterprise Management / Physical

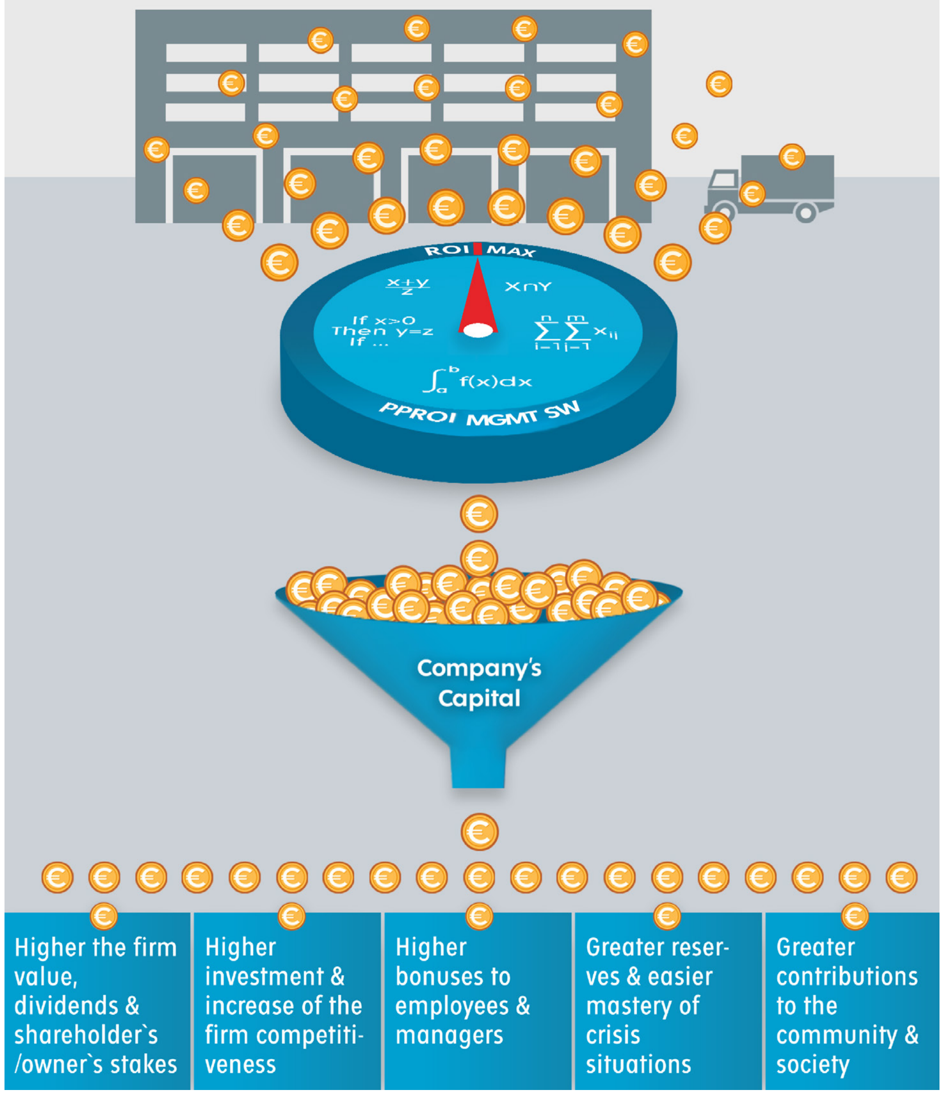
This last part deals with PPROI's information in physical units of measure. The overall idea of the groups of this information, their content, links and projection into financial variables is provided by the scheme of the PPROI architecture presented in the introductory part on page 0–8.
Information on products, resources and physical territories is much broader than in ERP, both in order to manage physical processes beyond traditional production and to achieve accurate financial information generated by specific resources. Separate resource-related modules PPROI contains for operators, according their abilities to serve different work centers, and for maintenance of machines and tools. Information on production processes is completely new, from the description of microphases of operations through process standards to production plans.

Content of Part 0

Why New Management Software is a Must / Why PPROI

0. Why PPROI Respecting the Laws of Nature - the End of Wasting Resources

PPROI – End of capital wasting due to information systems weaknesses



PPROI's management concept as implementation of the basic law of economics

The PPROI concept of enterprise management expressed by words „Aligning products, processes and resources to maximize ROI" merges the universal objective of any business given by economic nature with the means to achieve this objective. Only under this assumption is the basic economic law practically respected. As the enterprise ROI is the weighted average of ROI values in processes by products it is necessary to manage each of these processes to ROI MAX. If not, managers ignore enterprise objective, its ROI value is much lower than it should be, the enterprise wastes resources.

Before PPROI: Absence of key information, mismanagement, far-reaching consequences

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

Financial information about processes by products is very poor, both in management theory and in enterprise information systems. Information on capital employed (CE) and ROI does not exist at all, information on product costs is distorted and misleading, the pricing formula assumes proportionality of profit to costs, which is wrong. In this situation enterprise managers are financially blind, the enterprise ROI is well below achievable possibilities, wastage of resources financially reflected in the capital wastage is huge. The enterprise stakeholders and the public suffer, the countries' wealth is growing more slowly than it could, if at all.

PPROI: Comprehensive, specific, correct information, management to ROI MAX

$$\underset{\text{Maximized}}{\text{ROI}} = \frac{\underset{\text{New pricing formula}}{\text{Price}} - \underset{\text{Optimized}}{\text{Costs}}}{\underset{\text{Optimized}}{\text{Capital Employed}}}$$

Brand new, comprehensive and accurate financial information about products, their processes and resources opens managers' eyes, and projection of all elementary parameters of products, processes and resources into costs, CE and ROI in processes for individual products and finally into the ROI of the enterprise enables to choose the alternatives so that the ROI is maximized. As the values of the various sub-variables in the compared alternatives often behave in the opposite direction, their values in the best alternative, with ROI MAX, are optimized. This also applies to costs and CE. Waste of capital is eliminated for the common good.

However, it is possible only through completely new PPROI management software, in which all sub-variables are linked with math functions, and which behaves as the real system, the enterprise itself.

Environmental and social constraints in maximizing ROI

In an effort to achieve any economic objective, it is necessary to respect environmental constraints.. Aiming at ROI MAX leads to minimum drawing natural resources for the given products and compared to other methods of economic management of the enterprise is environmentally most considerate.

0. Why PPROI Using Definite Integral to Measure Capital Employed and ROI

The condition for the entry of enterprise management into the area of science

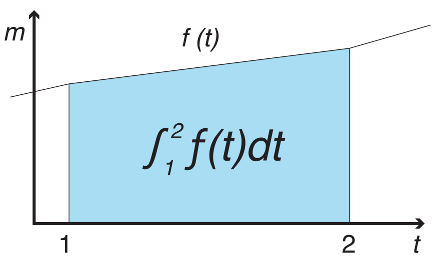
„If you cannot measure what you are speaking about, then it is not science.“ Lord Kelvin

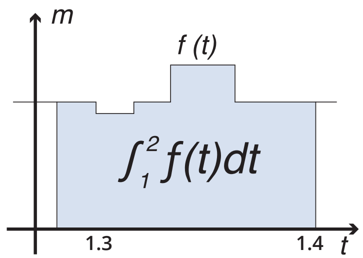
To the uninitiated reader in enterprise information systems, it seems incredible that there is no information about capital employed in specific processes. Everyone in any industrial enterprise can see the processing operation of a certain part of product provided by the machine. The value of this machine and the product part itself represent two of many components of the CE, to which the financial yield – product profit should have corresponded.
In our opinion, the basic reason for the absence of this essential information is clear. Measuring CE in a certain period requires the application of a definite integral and the expression of its value in moneytime units. However, neither information systems nor management theory contain this type of variable. CE and ROI in processes by products cannot be measured. In the management of the enterprise its objective goal is ignored, managers grope and manage the enterprise incorrectly in front of the closed gate of science. Resulting capital wastage is enormous though unknown and not perceived.

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

An understanding a definite integral is one of the foundations of managers' financial literacy. However, as we have experienced, the very words „definite integral“ arouses resistance among managers, which grows with its notation as $\int_a^b f(x)dx$

It is perceived as high mathematics that is useless in economic practice. Therefore, we will explain here its meaningfulness and use.
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 a standard example, a function has the character of a continuous curve, but this may not be the case. It can be straight lines, which are constant and/or increasing and/or decreasing, and the values can also change abruptly.
The variable on the y-axis can be money, the variable on the x-axis can be time, its boundary points a, b can be denoted as moments 1, 2 and a definite integral then denoted $\int_1^2 f(t)dt$.



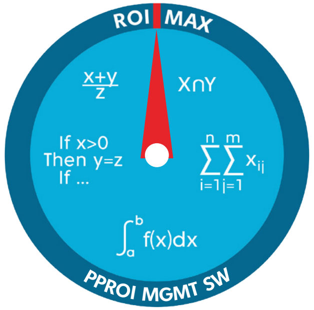


Date	Stock €	Stock from 1.3. to the date €Day	€Year
1. 3.	5000		
4. 3.	4300	15000	41.10
10. 3.	5100	40800	111.78
15. 3.	6700	61200	167.67
22. 3.	5200	114800	314.52
1. 4.	5200	166800	456.99

When measuring capital employed in enterprise physical processes
• the variable on the horizontal axis is the process time; points 1 and 2 are the starting and ending moments of a certain process phase, either processing or logistical
• the variable on the horizontal axis is the monetary value of a particular physical item, such as a part of a BOM
• the variable characterizing CE by a definite integral is two-dimensional, expressed in moneytime units of measure.
Units of time and money can vary, and their choice determines the capital employed units of measure, e.g., €, Year, ⟶€Year

The figure and table above characterize the continuous stocks of capital in money form on a specific bank account during the month of March. The area of definite integral from the beginning of March 1 to the beginning of April 1, calculated when time is measured in days, is converted in time expressed in years. The account holder receives the yield on this CE according to 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. However, basic presumption for its calculation, i.e. measurement of CE, is solved.

Application of previously unused mathematical apparatus in management



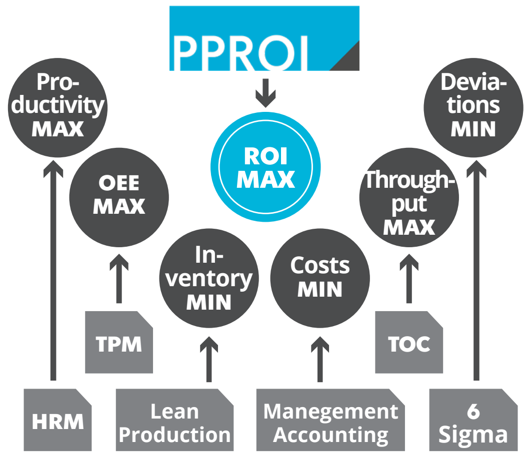
We are aware that explaining the definite integral and its usefulness at the very beginning of a PPROI presentation can provoke displeasure. Our acquaintances warn us not to do so, because current managers mostly do not perceive management as a science and prefer „soft disciplines“ focused on people's feelings to mathematically substantiated procedures. If any presentation starts with a term „integral“, they may lose interest in the matter. This is all the more so as in previous management education they usually encountered only very simple algebraic formulas. In contrast, mathematically erudite people in companies may perceive the explanation of a definite integral as a personal insult. However, if without the application of a definite integral it is not possible to quantify economic concepts that are crucial for the proper management of any business, there is no point in trying to get around the matter with with vague words. And it's not just a definite integral in measurement of CE and ROI. As outlined in the PPROI image, in the interest of systematic navigation of enterprise products, processes and resources to the enterprise goal, ROI MAX, other mathematical procedures new in management are applied in PPROI in addition to traditional ones. (Most of them only internally, in calculation procedures that system users do not need to know.) PPROI thus in fact reflects one of the two main trends in science on the threshold of the 3rd millennium, which experts have identified as the dissemination of the apparatus of mathematics that was previously regarded as useless in some disciplines..

It is quite likely that some readers of the previous text engaged in the history of management will reject our claim that enterprise management is outside the realm of science. After all, the foundations of scientific management were laid more than 100 years ago, and the author of the term „scientific management“ Louis Brandeis, labelled as its key financial concept the costs. However, this alone was a fundamental mistake, deeply rooted in managers' thinking so far, which has left managers hopelessly groping in front of the closed gate of science.

Exceeding the framework of highly specialized enterprise management

„Disappearing boundaries between disciplines“ has been identified as the second major trend in modern science. Too narrow a specialization can cause people to lose the wider context and create fundamental mistakes and contradictions. A better example of this situation than „management by costs“ is difficult to find. Luis Brandeis can be forgiven for a fundamental economic mistake because he was a lawyer. But it is inexcusable that this error is ignored to this day. After all, as early as 1914, Donaldson Brown, sometimes referred to as the father of ROI, created a model in which ROI is a synthetic variable and costs only a sub-variable, ie one of the factors of ROI. The current unnoticed contradiction and gap between management accounting and financial accounting is inexcusable as well. While management accounting ignores CE and ROI, financial accounting contains only company-wide data and is unusable for managing products, their processes and resources. This also applies to the pyramid of ratios designed by Donaldson Brown. PPROI removes this crucial information gap.

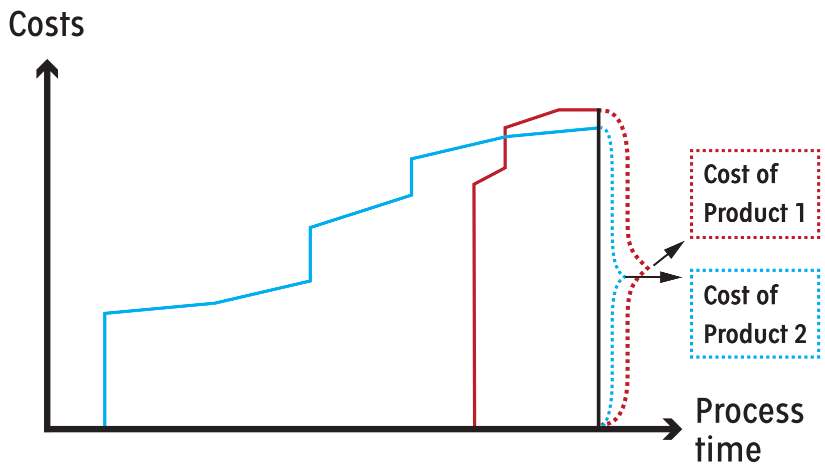
Kind of accounting	ROI, CE	Product, process
Financial	Yes	No
Management	No	Yes
PPROI	Yes	Yes



In addition to costs, the products, processes and resources are evaluated by a number of partial variables of a physical nature corresponding to specialized theories. For each of the variables, an effort is made to maximize or minimize their values. But this leads to conflicting solutions. The enterprise is treated as a set of independent fragments. However, the enterprise is and should be treated as an organism, in the current sense of the term: „A living, self-sustaining system with properties and functions determined by the properties and relations of its individual parts and by the relationships of the parts to the whole.“ This is the case in PPROI, where all sub-variables in the interrelationships are projected into enterprise ROI and at its maximum value the values of the sub-variables are optimized.

Product costs from a mathematical point of view and their incorrect use

As the CE in processes by products and their ROI are not measured, process alternatives for a certain product are evaluated according to costs and different products are evaluated according to profit-to-cost ratio, usually called cost efficiency (or by the profit-to-price ratio, called profitability). This means that the time of capital turnover is ignored and elementary financial logic is denied. This is shocking and has tremendous negative consequences. But to fully clarify this situation and its consequences in a broader context, it is first necessary to define the term „cost of the product" resp. „product costs" from a mathematical point of view. Since we have not found such a definition in any literature, we have dedicated this page to the issue and illustrate it in the image below. The crucial problem is the definition of the cost of product at point in time. Expecting a financial yield from instantaneous monetary value is senseless in general.
The functions outline the development of costs in processes for two products. For product 1 by the red line, for product 2 by the blue line. Instantaneous values on the vertical lines during processes express the inputs of purchased materials in monetary form, ie., direct material costs. Other costs increase linearly during the processes, but at some points of time the slopes of the straight line, ie., the growth rates, change. These are points of time when resources in processes change. For the slope of the straight line within a certain phase, the cost increase generated by each resource per unit of time, usually per minute, is decisive. E.g. at a certain phase of processing the part of BOM, a specific machine generates the cost of electricity, which drives the machine; these costs are determined by electricity consumption per minute and electricity price. Another cost generated by the machine is depreciation resulting from the machine price, its lifetime in minutes and time utilization. These two types of costs per minute are different, ie. have different slopes of the straight line. Other costs within a phase may include the cost of a particular drill, determined by the drill life until blunt, the number of sharpenings, the price of the drill, and the cost of sharpening. If workers operate in the phase, the costs they generate per minute are determined by the number of operators in the phase, total annual labor costs payed by an enterprise, the number of working minutes per year and the time utilization of operators. The slopes of the straight line for a respective phase is the sum of slopes of the straight line defined for all resources in the phase. By multiplying this final slope of the straight line by the time of respective process phase, the costs during process phase arise. These connect on the final previous value of the function.



The latest values of both functions in picture express the cost of each product. These are defined at the moment of product sale. Areas under individual functions are definite integrals characterizing CE in inventories. The cost of product 1 is higher than the cost of product 2, the opposite is true of CE. The reason is a significantly larger scope of processes within the respective enterprise for product 2. Processes for product 2 probably also requires much higher demands on machinery and equipment and building spaces, ie., much higher fixed CE. Thus, it can be realistically assumed that the total CE for product 2 is about three times higher than for product 1. A triple yield should correspond to this. However, because product 1 has higher costs, the standard product pricing through a percentage profit mark-up on costs sets a higher absolute profit for it. This is absurd, but managers have no alternative, as there is no information on CE.

Analogy of the required interest from the instant stock of money in a bank account

Let's go back to the example on page 0-2 and assume that the account holder opened an account and deposited the first money on it on 22.3. in the amount of € 5200. This deposit did not change until the end of March. The account holder on April 1.4. demands interest according to interest rate for the all month of March corresponding to the amount of money in the account on March 31 at 24:00. This person should be considered a financialy ignorant. However, in the management of enterprise products and processes, this absurd thinking, assessment and decision making is normal.

0. Why PPROI Values of Financial Variables from Supply Chain Point of View

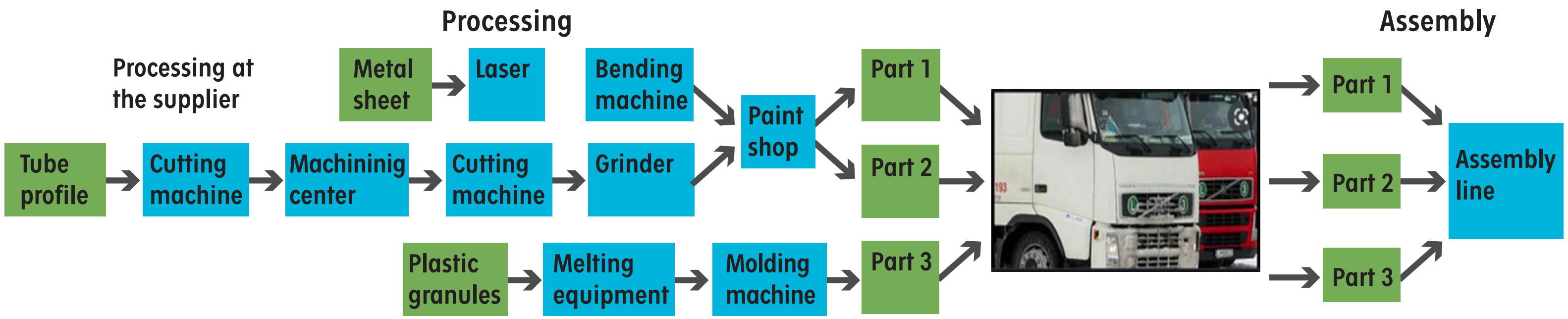
Financial variables as parameters of capital

Clarifying the concept of product costs as a value defined at a certain point in time and the possibility of lower costs for a certain product with significantly more extensive processes compared to another product, which the picture on the previous page demonstrates, likely surprised the vast majority of readers. This is all the more so as it revealed the absurdity of traditional product pricing. The mathematical properties of values of financial variables must be understood not only in terms of one enterprise but also in their links with values in upstream enterprises within the supply chain. This page is devoted to this issue. Primary, however, is the definition of terms from content point of view. If, for example, the ratio of CE to costs expresses the time of capital turnover, then costs must also be an attribute of capital. It is true and the same is true for all financial variables. Costs may and should be defined as consumed capital, product price as created capital, profit as increased capital, and ROI as a rate of capital reproduction. However, the values of these variables relate to a particular enterprise or other type of firm selling products. The data in the table may be relevant for products 1 and 2 on the previous page.

Product	Costs €	CE €/Year	Capital tunover time *Year*
1	108	40	0.37
2	100	120	1.2

Dependence of product costs on the inter-firm supply chain

There is a general notion that costs are a measure of resource consumption and therefore „the lower the product costs, the better for the enterprise and society". But this is a false axiom which we will quickly refute using the following example. With the constant physical processes and resources outlined in the figure, the cost of the enterprise product, as an output of assembly line, increases, the smaller the scope of the processes within the respective enterprise. The product has the lowest costs when all processing operations and assembly as well as transport between the plant producing the parts and the remote plant dealing with their assembly take place within one enterprise.



If the processes for part 1 and / or 2 and / or 3 take place in another enterprise and the enterprise in which the assembly takes place purchases these parts, the cost of the product is higher by the suppliers' profits. And prices, formed by percentage mark-ups to costs according to the required cost efficiency. also rise. See table on the right.

Enterprise	Phase	Costs	Cost efficiency	Price
A	Processing	200	0.1	200+20=220
B	Assembly	220+50=270	0.1	270+27=297
C	Processing+Assembly	200+50=250	0.1	250+25=275

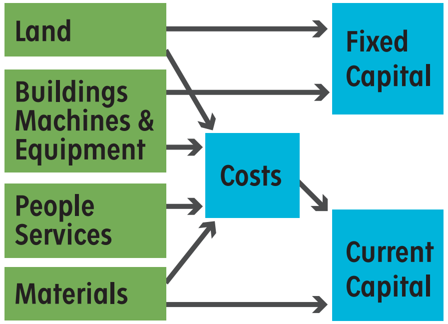
CE, profit and ROI values within the supply chain

In traditional price formation, enterprise profits grow as the share of purchased parts grows. In the table above, when the product, an output of the assembly, is produced in a chain of enterprises A and B, these enterprises together have a profit of 20 + 27 = 47. When the product is produced within one enterprise, ie enterprise C, its profit is only 275-250 = 25. But in our example, there is no reason for that to be. In both cases, the production requires the same machines and other resources, which are located in either one or two enterprises. With logical calculation of product prices according to CE and the required same ROI value, the price of the final product and the sum of profits are same in both alternatives. See table on the right.

Enterprise	Phase	Costs	CE	ROI	Profit	Price
A	Processing	200	150	0.1	15	200+15=215
B	Assembly	215+50=265	30	0.1	3	265+3=268
C	Processing+Assembly	200+50=250	180	0.1	18	250+18=268

0. Why PPROI Enterprise Resources in terms of their Impact on Costs and CE

Structure of resources according to their impact on costs and CE components



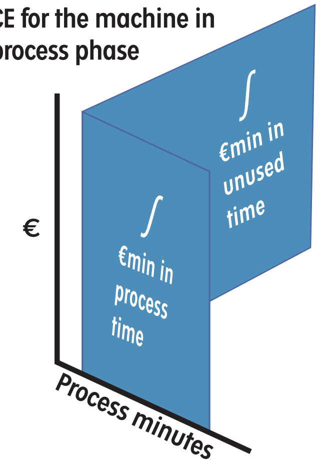
Both costs and CE are generated by specific resources. However, the impact of individual components of resources on total costs and total CE is different. This applies both at the enterprise-wide level and to processes defined by products. On the previous page, we clarified that as the share of purchased material increases, the CE in the processes for a certain product decreases due to the reduction of the scope of processes for the product within the enterprise. But even within same process scope for a certain product, a different resource structure can have opposite effect on costs and CE. This follows from the framework diagram of the relationship of the main types of resources to the costs and components of CE.

As for CE
- Land, buildings, machinery and other equipment are projected into fixed capital, which typically accounts for the majority of the overall CE
- People and services are projected into current capital through costs; these resources do not in themselves constitute CE
- Purchased materials, whether direct or indirect, which are in inventories represent current capital per se; In addition, like other resources, they are reflected in current capital through costs

In terms of the impact on costs, land is separated in the scheme from buildings, machinery and equipment, because land does not generate depreciation. Of crucial importance is the fact that machines are among the resources with the greatest impact on fixed capital and thus on the overall CE, and conversely, people are among the resources with the least impact on CE. Therefore, if the financial demands of products on resources are judged only on the basis of costs, machines are underestimated in comparison with people, because the demands of machines on CE are ignored. The situation is all the worse because traditional cost calculations do not contain information on the costs generated by the machines; so for automated and robotic production, these calculations are worthless overall.
An objective assessment of the overall financial demands of processes on machines and people is currently extremely important when deciding on robotics. We comment on this issue in the Financial section on p. 2-14, where we deal with the financial demands of people and machines in a broader context.

Calculation of fixed capital and fixed costs in processes by products

CE for the machine in process phase



Management accounting, among others, breaks down costs into variable and fixed. Variable costs per product are independent of its amount in a given period. Fixed costs are constant for the enterprise as a whole and for a certain product are indirectly dependent on its amount. However, this is true when only one product is produced within the enterprise. With a wider product portfolio, the fixed costs for a given product depend on the quantity and process scope of all products.
Buildings, machines and equipment operating in direct processes on products generate fixed capital and fixed costs linked to certain process phases, depending on the time of the phases and the time utilization of a particular resources. The time utilization of a certain resource depends on the total number of different parts that are processed by the resource during the monitored period and on the processing times of individual parts. PPROI automatically calculates this use and subsequently calculates the fixed capital and fixed costs generated by the resource at the time when this resource is used in the processes and the corresponding values when the resource is unused. The figure on the left illustrates both of these components of fixed capital for a certain machine within a certain process phase. The same relation applies to depreciation, which is fixed costs. For different resources, the shares of fixed capital and fixed costs at the times of use and non-use of the resource differ.
Resources in indirect territories generate costs and CE, which, with marginal exceptions, are fixed. In PPROI, these are relevantly allocated to items of direct process phases, the amount of which changes as the product portfolio changes. With the growth of the quantity and / or the process scope of products in the monitored period, these costs and CE for individual products decrease. Thus, the decrease occurs in a different way than in direct fixed capital and direct fixed costs.

Inventories and labor productivity versus utilization of machines

As mentioned in the Foreword to this document, one of the main reasons for the development of PPROI was the information support of lean manufacturing which we have implemented in industrial companies. Even this type of production is necessary to submit to the ROI criterion. If it is focused only on the usually emphasized inventory minimization, its implementation can be inefficient, leading to decreased ROI value, ie to waste. Inventories, like any other sub-variable, should be optimized, not minimized (see p. 0-3). We will explain the issue on this page with an example. Production operations on BOM parts in traditional production take place at isolated work centers, with independent setup and processing times. Production lots of parts must therefore be transported between work centers and wait in queues. This requires logistics costs and CE in inventories and fixed capital in transport equipment and production hall space. Operators utilization may be low due to their waiting for the machine to complete automatic processing.
In lean production, work centers are laied out in lines according to the process sequence of operations, there is a smooth flow of individual product parts between work centers, one operator can operate more work centers and with more operators in the line they can optimally divide the work.
In the example, when the line is operated by one operator, the takt time is 1.5 minutes, when the line is operated by two operators, the takt time is 1.2 minutes. This is the shortest possible takt time determined by the bottleneck of the line, which is the machine at work center 3 for which the sum of the times for parts replacement and automatic processing = 1.2 minutes. Operators are not fully utilized. In both cases, however, labor productivity is much higher than in traditional production, where the time for one part, which the operators spend together in all work centers is 3.3 minutes. In lean production, the run time of the production lot is more than twice as short even when the line is operated by one operator. Both labor costs and CE in inventories are much lower than in traditional product processing. If we add to these benefits the elimination of logistics costs and CE of traditional production, the overall financial benefits of lean production are fascinating. The disadvantage, however, is the low time usage of some machines. While in traditional production the machine at work center 2 is bound for the same production lot for only 60 minutes, in lean production it is at least 360 minutes. If the same machine is missing elsewhere, the enterprise needs to have additional machines, ie., excessive fixed capital and depreciation. And if the processes for different parts have different sequences of operations, many little-used lines and thus machines can be created. Processes „lean“ in terms of current capital are „thick“ in terms of fixed capital. It is therefore necessary to optimize the number of production lines and work centers within the lines, while some separate work centers cannot be excluded. The evaluation and decision-making criterion must be ROI.

Traditional production

Work center	Operator; Manual work *Minute*	Machine; Replacement of parts *Minute*	Machine; Automatic processing *Minute*	Run time per piece *Minute*	Production lot *Number*	Run time of lot *Minute*
1	0.5	0.2	0.8	1	300	300
2	0.2	0.1	0.1	0.2	300	60
3	0.4	0.2	1	1.2	300	360
4	0.4	0.2	0.7	0.9	300	270
Total	1.5			3.3		990

Lean production

Line of work centers	Bottleneck; Work center 3 *Minute*	Takt time; 1 operator *Minute*	Takt time; 2 operator *Minute*	Production lot *Number*	Run time of lot 1 operator *Minute*	Run time of lot 2 operators *Minute*
1, 2, 3, 4	1.2	1.5	1.2	300	450	360

Lean production from supply chain point of view

J. P. Womack and D.T. Jones in the book „Lean Thinking“ from 1996, documented the lead time of production of can for Coca Cola from mining raw material as 22 weeks. In contrast, William A. Levinson quotes H. Ford in the book „Henry Ford‘s Lean Vision“ that their production cycle is about 81 hours from the extraction of raw materials to the shipment of the finished car. The basic problem of current production is the cutting of processes into many enterprises and extremely demanding intercompany transport and storage. The supply chain is very fragile and negative consequences for the environment are high. And the applicability of lean manufacturing in companies with few operations on produced parts is limited. The only way out of this undesirable situation is the reintegration of processes, which current technologies allow. We have encountered this in some current companies and we pay attention to it in the PPROI Demo.

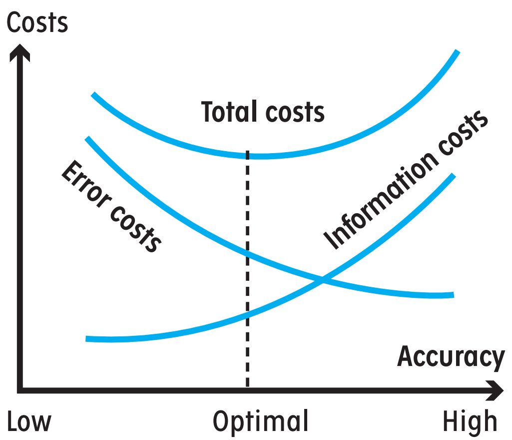
0. Why PPROI Necessity and Methods of Determining the Correct Values of Variables

Oversimplified and misleading traditional calculations of product costs

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

On the previous two pages, we pointed out the serious negative consequences of the absence of information on CE and ROI in processes by products. These variables, irreplaceable for the proper management of the enterprise, are completely missing in management theory. Information on product costs exists, but due to over simplified calculations, it dramatically distorts reality. For this reason, management accounting has even been labeled as „the enemy of enterprise No. 1". In this situation, the financial management of the enterprise takes place in total information darkness, mismanagement and waste are permanent. The correct values need to be determined for all variables. The PPROI procedures used to correctly calculate costs and CE in processes according to products are explained in Part 2 of this document, abbreviated as Financial. The conceptual approach outlined already on page 0-2 for calculating CE is also applied in calculating costs. However, the calculations of the values of these two types of variables also have specifics.
ROI values in processes by products and enterprise ROI arise as a math function of values of costs and CE in processes by products and prices of products.

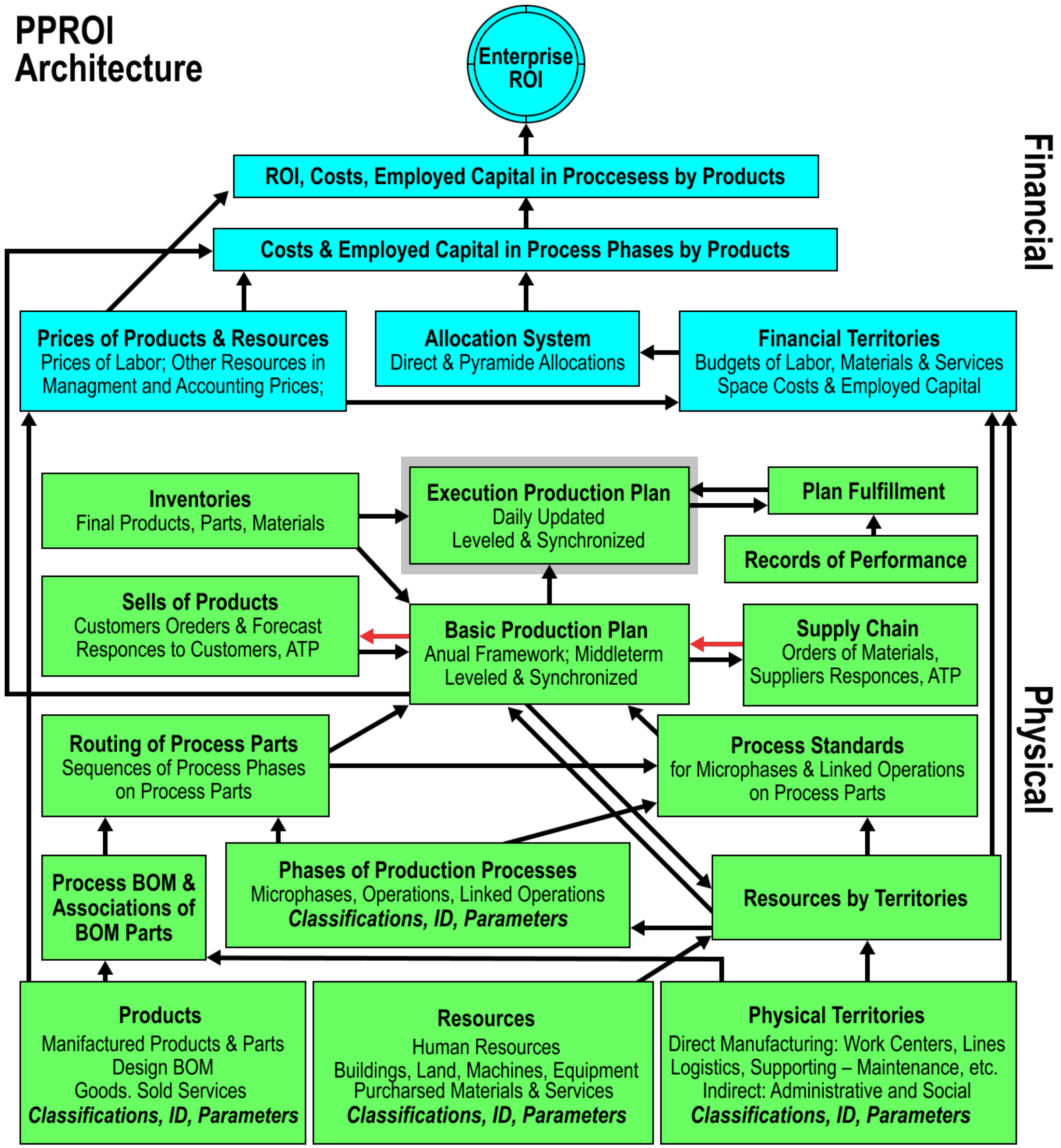
Optimal management information at the present time



One of the deep-rooted axioms is the following statement about economically optimal information: "Missing or inaccurate information generates business management errors that increase objectively necessary business costs. But improving information, i.e. increasing its quantity and accuracy, requires increased costs of obtaining input data and their processing. Optimal is such information, where the sum of these two cost components associated with the information is minimal." This axiom is even demonstrated by the type of graph on the left. Perhaps this axiom is one of the main reasons for the long-term stagnant poor state of enterprise information about its products, processes and resources.
The labor and financial demands of obtaining complete, specific and accurate information are changing. Multiple reduction of these demands compared to the past is made possible by current computer technology. Full and correct use of its potential, however, is conditioned by new structuring of information in terms of its content, new system of economic variables and their mathematical functions, designed to ensure maximum information outputs from a minimum of inputs. Mathematical prescriptions must be logically justified and written in a form suitable for IT programmers. The correct implementation of math prescriptions into computer software must be thoroughly verified. This is the case in PPROI, which has no parallel yet. In creating PPROI, we had in mind Einstein's recommendation to make it as simple as possible, but no simpler.

The paradox of excessive simplification: useless work

Traditional calculations of product costs in industrial enterprises are based on the principle of determining direct material costs according to the BOM and wages of operators at processing work centers and increase of these two components by overhead surcharges. The procedures in determining surcharges vary. Excel is currently used for calculations. Managers of individual companies are convinced that their calculation procedures are the best and some companies require in the price negotiation from potential suppliers of components to prove their costs according to the buyer's calculation methodology. The supplier of the same product to different customers has to perform other calculations for customers in addition to its own calculation method. The calculated values differ and all are wrong. The reason is mathematically clear. Percentage surcharges only make sense in the case of a direct linear dependence of other cost components on direct material and / or direct wages. However, this is not the case with any of the other cost components. All the work involved in the calculations is wasted. Oversimplification breeds useless work with information also in other contexts. Current enterprises are overwhelmed by calculations of many people in Excel with little effects.



Main groups of PPROI information and their links

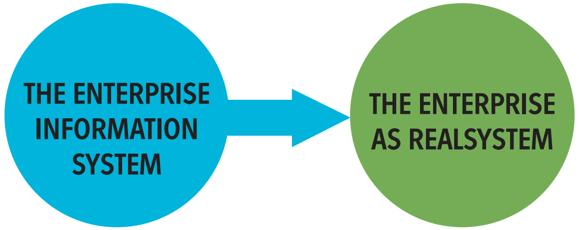
In the first phase of PPROI development, the basic groups of information in terms of content and their logical links were defined and expressed in the system architecture. As visible from the left diagram at first glance, all the physical parameters of products, processes and resources specified according to enterprise territories are gradually projected into the financial parameters of processes by products and finally into the enterprise ROI. The top arrows in pairs indicate feedback, the red arrows limit the requirements by production and suppliers' capacities.
After the conversion of content-defined terms and their logical relations into the means of mathematics, ie variables and their functions and subsequently into the means of informatics, PPROI acts as a living system, an enterprise itself.

Physical. The information in the Physical section characterizing enterprise products, resources and processes from physical aspects in physical unites of measure differs from the same focused information in ERP in multiply aspects:
Scope: PPROI fully supports lean manufacturing and other progressive solutions beyond traditional production processes reflected in the ERP.
Content: PPROI contains a much larger quantity and higher quality of information than ERP in terms of completeness, detail and accuracy.
Mathematics: Final output of the Physical section, the Execution Production Plan, determining in real time what and where have to be done synchronizes processes on different BOM parts is created by conditional functions and other means of mathematics never used in ERP. It thus replaces the oversimplified and unfeasible MRP plan, for which ERPs are often criticized as a whole.

Financial. The information in this section has no counterpart in ERP. New financial data evaluates in detail existing physical solutions and alternatives to their replacement in strategic decision making and continuous improvement. The enterprise's ROI fulfills the role of comprehensive criterion, navigating all managers and other people to optimal, most efficient physical solutions.

0. Why PPROI Essential Problems of ERP and their Conceptual Solutions

The impact of the information system on the attributes of the enterprise and the roots of ERP problems



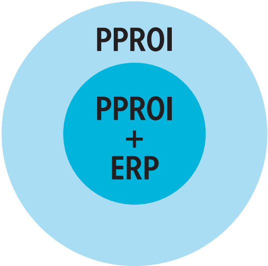
The fundamental weaknesses of management information, a substantial part of which we have described in the previous pages, are clearly provable in enterprise information systems, currently called Enterprise Resource Planning. This information lacks key variables and existing information is fragmented, oversimplified, outdated and therefore misleading. It has a very negative direct impact on the attributes of the enterprise itself. As mentioned in the foreword to this document, the problems of this information are long-term as even current ERP is based on procedures for the management of production processes, established more than 100 years ago within the so-called scientific management. In our opinion, the solution of essential problems of ERP is therefore possible only through conceptual changes of this historical basis of ERP. That's how we approached the development of PPROI. The problems are further divided into three groups, but these are intertwined.

Multiple enhancement of the scope and depth of ERP information

Crucial ERP's flaw is undoubtedly the complete absence of information on employed capital and ROI in processes by products. For this reason, ERPs cannot navigate enterprises to their objective. And product cost information is not only incomplete, but some cost components are even meaningless. Most ERPs contain as an attribute (variable) for each work center the minute costs of the respective center. But there is no such thing, and if a user records a certain value for a certain work center, it is an unfeasible fiction. Operations on different BOM parts in a given work center usually have different per-minute variable costs, and in addition, per-minute fixed costs vary in a given center depending on the product portfolio during the period under review.

Proper cost calculations require information about resources and their times within operations. In ERP, however, the elementary process phase is the operation so the problem has no solution. The PPROI solution consists in the division of processing operations into microphases, recording resources and their times in each microphase, separate records of costs that generate individual resources in their active and inactive time per time unit and following calculation of costs that individual resources generate in each microphase.
PPROI also contains new information structures for the calculation of costs and CE generated by specific resources in the logistics phases of direct processes and in indirect territories.

Beyond traditional production processes



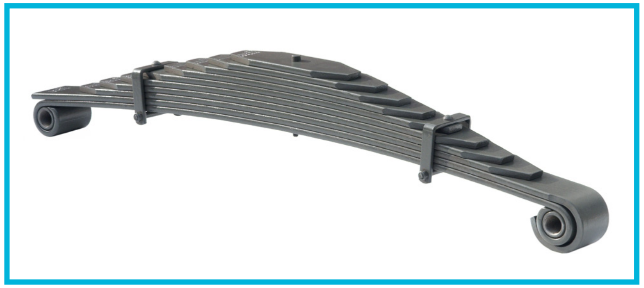
The division of processing operations into microphases is also essential for the physical management of lean production. Within a given operation, there may be a number of consecutive microphases that differ in resources and their activity. For example, a certain microphase is defined for the combination of an active handling robot with a passive processing machine when removing and inserting parts from (into) the machine. Based on the information on microphases of operations, PPROI automatically calculates variant takt times of linked operations in production lines for different allowable numbers of operators while respecting bottlenecks.
The processing operations described in ERP relate to the lots of the individual parts of the BOM. In practice, however, parallel or closely followed processing of different parts of the BOM is increasingly common, which saves a number of setups and manipulations. PPROI information covers also these processes. Because in PPROI, a separate operation is considered a special case of linked operations and a operation on a separate BOM part is considered a special case of operations in which several different BOM parts are processed in parallel, all possible combinations can be registered and standardized within one PPROI module.

Leveled production plans

ERP is most often criticized by experts and users for the unfeasibility of the MRP plan. Only efforts to create so-called finite plans by eliminating work center overloading do not help. It is also necessary to ensure leveled demands on operators. However, this is only possible by leaving the very basis of MRP algorithms, ie., a priori setting of constant lead times of production lots of BOM parts. Using unique algorithms, PPROI generates leveled plans in the long term outlook. Otherwise, material deliveries miss the real-time production needs. This is reflected in the discrepancies between the production phases and between production and shipping requirements. This total permanent chaos significantly reduces the ROI values.

Ing. Radek Páleník

CFO,
before that Production Director,
before that IT Manager for
HZP Prostejov



When the company's CEO and CFO, having completed a two-day Executive development program at the Prague University of Economics and Business, presented a proposal to our company's managers to transform the enterprise into a lean firm according to ROI, including basic changes of the information system, I was the lone opponent. I have worked in IT for nearly 15 years. I myself programmed a substantial part of the information system, and so I had the opportunity to look deep into the nuts and bolts of ERP systems. A basic change of these traditional, conceptually identical systems seemed impossible to me.

As soon as they began working at our company, the staff of the CEPC consulting firm addressed the need to rework all process routings and replace all time standards as a necessary condition for introducing truly lean production. This involved over 4,000 active product parts, over 70,000 operations, and more than 200,000 time standards determined outside the IS, on which technologists and standardizers had been working for dozens of years. The absurdity of the target, in my eyes, only grew when addressing the requirement to break down operations into microphases and to set detailed physical and financial parameters for each of them. To me, this meant tens of millions of hand data records into the IS and unimaginable demands on determining standards, as well as financial numbers outside of ERP. On the other hand, based on video recordings and analyses the CEPC consultants documented for us how our standards were incorrect and were unusable for planning and managing lean production. So, I felt that we were in a trap – facing the need to solve a key problem, but in terms of the work required the problem could not be solved. Today all of us at the company know that the problem can be solved, very effectively, but not by procedures that are traditionally used. The description of the process encompassed **science – mathematics in particular, in a way we had never heard of, had never thought about, had never dreamed of.**

Today I speak of PPROI as the harbinger of a new generation of information systems. PPROI's characteristics exceed all imaginable criteria. In connection with the properties of PPROI, for the first time what the term, **"integration of data,"** was supposed to mean really dawned on me. The full interrelationship of information through mathematical functions in PPROI automatically reflects the physical parameters and prices of individual resources and products on the company's ROI. It leads everyone, during improvement or optimization, in all positions in the company, for affecting the ROI as best as he can. In ERP systems this is unimaginable.

Leap from the era of darkness and groping into the era of science

The image on the left clearly characterizes the situation in ERP. If someone wants to get information on CE and ROI in processes by products and thus about the efficiency of individual products themselves, they don't gain anything at all from ERP. This key information does not exist anywhere else. As information on product costs is completely inadequate, if not diametrically skewed, it is a mystery to us how the company's financial results are analyzed in regular monthly reports. However, it is not just about evaluating and analyzing past financial results. For the planned period, among other things, it is necessary to calculate

- What will be the ROI of each product and the enterprise in the planned product portfolio
- How existing machines and equipment will be used and how this will affect ROI
- How projected energy prices will reflect the ROI of individual products and the enterprise

The most important is the targeted improvement of the enterprise own processes according to ROI.

Nothing should stagnate. However, any change has alternatives that need to be assessed.

This applies to strategic decisions as well as to continuous improvement. As follows from the previous text, it is necessary to assess the possibilities of own production of some items instead of their purchase and to optimize the overall relationships within the supply chain. Expanding lean processes and robotics need to be optimized. It is necessary to permanently reduce the defects of processes, but in the most efficient way. Indirect processes should not stagnate either, and their changes should be reflected in their costs, CE and finally in ROI. Salesmen must have the right information on costs and CE of enterprise products to negotiate price with customers so as not to undermine the enterprise ROI but help increase it. Etc., etc. Prior to PPROI, however, all people in the enterprise, in all contexts, lacked necessary financial information. **The very first calculation of the values of key variables using PPROI, illustrated in the tablet, means enlightenment, a unique leap from information darkness into the realm of science.**

PPROI ROI IN ACTION

Product	CE	ROI
1	9000	0.20
2	5000	-0.04
3	6000	0.05
Total	20000	0.095

The need to teach enterprise management by software filled with data

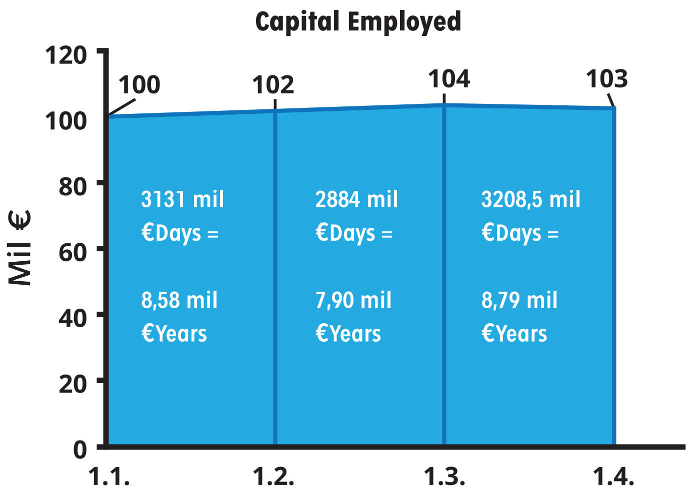
The pictures make clear that management accounting and ERP contain the same problem: ignoring the existence of capital employed in processes and thus necessarily the ROI of products. The problems are also same, as far as cost information is concerned. The only cost components generated by specific resources are direct material and labor costs. Management accounting does not clearly define even these components, nor are the definitions of these components in the various ERPs uniform. E.g., calculations of both components, usually disregard process defects

Examining whether management accounting or ERP is responsible for this will not help. In PPROI, this vicious circle has been removed by building a new information system from the ground up. Business school students, unaffected by previous incorrect education, should be the first to understand enterprise as a controlled organism, its natural objective and the means to achieve it. But such an insight requires a practical example that shows how to run an enterprise. We are almost certain that they will accept it as logical, they will understand the application of a definite integral quickly and after a general acquaintance with the issue, roughly within the scope of the text of this document, they will request the software itself to be able to use it. At a time when all young people are using a computer, smart phone and / or tablets, it is natural. However, the software must be filled with data that characterizes the enterprise to a reasonable extent. It must be a fictitious enterprise, because specific companies keep their know-how. The case study of the finance section of this document focuses on an enterprise that makes hats. For the demo version of the PPROI software, we chose an enterprise producing scooters. Not only the product is understandable, but also the manufacturing processes using machines common in metal and plastic processing.

The question is what will happen to traditional management accounting, with its one-sided focus and oversimplified models. The same question applies to multiple management disciplines. The answer is clear: Scientific breakthroughs result in the end of previous false theories in general and everywhere. The sooner the better. PPROI Demo can be used not only at business schools but also to re-educate managers in practice. So we are striving for its wide availability.

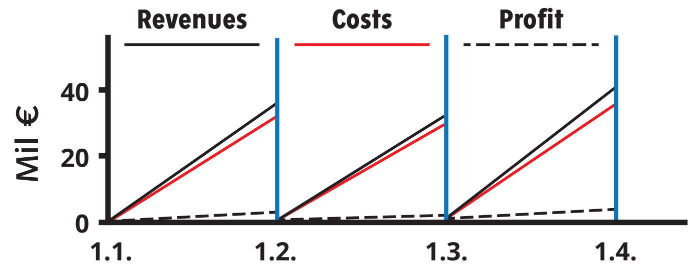
Content of Part 2

Brand New System of Financial Information / Financial



Definite integrals of capital employed in standard calendar periods

The immediate states of capital employed (CE) change mostly as a result of acquisition and scrap or sales of machinery and other equipment and due to fluctuations of inventories. These changes over standard calendar periods are usually relatively small - within single-digit percentages. The moments of recording capital stocks are usually the beginnings of individual months and linear development is assumed between these successive moments. The length of each month is measured in calendar days. As the figure on the left illustrates, the numerical value of the definite integral of employed capital in each month depends on the used units of money and time. Values calculated in €Days are converted into €Years.
The values of the definite integrals calculated for successive time periods are addable. As seen in the table, the sum of the CE for the first three months is equal to the CE for the first quarter of the year. And the values of definite integrals in any time periods are usable in ratios with values of flow variables as is the case of ROI (see the table)



Attributes of flow variables

Flow variables are one-dimensional, in the case of financial variables measured in units of money. These variables are functions of time and are graphically displayed by lines. In the graph, revenues are displayed by a solid black line, costs by a solid red line, profit by an intermittent black line. The values of the variables in the graph are displayed separately for each month. If characterizing the whole quarter, the values of all variables in the chart would grow continuously to final values in the quarter. The growth rate of each variable within the month in the graph is unchanged, daily fluctuations can not be captured in our graph. Values of flow variables at the end point of the period are interpreted as values defined for the period.

Period	CE mil €Year	Revenues mil €	Costs mil €	Profit mil €	Profitability €/€	ROI €/€Year
January	8.58	36.42	35.34	1.08	0.031	0.126
February	7.90	32.08	31.12	0.96	0.031	0.122
March	8.79	41.05	39.62	1.43	0.036	0.163
1st Quarter	25.27	109.55	106.08	3.47	0.033	0.137

Ratios: Profitability and ROI

While profitability is the ratio of two flow variables, ROI is the ratio of flow and stock variables. This fundamental difference in itself causes a completely different evaluation of the company's financial results by these ratios. In the example, profitability is unusually low, with ROI values being quite good. This may be the case in a situation where the enterprise only deals with the assembly of final products and buys all components. The time of capital turnover is short, and the result can be a favorable ROI value. Even at the enterprise level profitability is just one of the factors ROI, which may act in opposite directions. But these factors cannot be managed at the enterprise level because their enterprise values are the result of product, process, and resource management.

Basic principles and terminology

Processes by products are monitored for BOM items related to individual final products, including processes on the final products themselves. These processes are divided into phases with different resources. Times of these phases and resources within phases are registered. The system calculates costs and CE which individual resources generate from the input parameters of resources and times of process phases. All resources operating in these phases as well as the costs and CEs they generate are considered direct in relation to the relevant final products. The processes on the manufactured parts are partly processing, partly logistical. During the processing phases the manufactured parts change shapes and other physical properties, thus creating new products. Processes on purchased materials and on finished products are exclusively logistical. PPROI procedures are therefore fully applicable not only for the management of industrial, but also for the management of logistics companies in order to maximize ROI.

The main groups of resources in direct processes per products are people, machines (incl. means of transport) and other equipment and parts of the buildings in which the processes take place. All these resources generate the cost of products, part of which is fixed, part variable. A separate component of direct products costs is direct material. Machinery and equipment, buildings and land contain fixed capital.

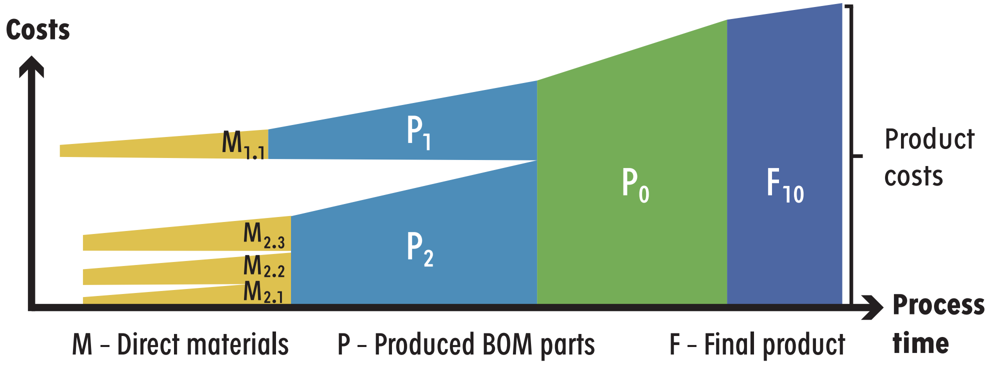
Costs and CE generated by resources in the administrative and other indirect territories of enterprise are also quantified. The values of these variables in the period considered are allocated to the direct process phases for products according to the support of direct processes by indirect territories.

The separately registered component of CE is current capital, contained in the BOM items and in the final product. Its value is linked to the development of the total cost of the product.

Mathematical links between capital employed and costs

As illustrated in the figure below, costs are one of the two variables defining integrals of CE in the BOM items for the respective product and in the final product itself. The second variable is process time.

Capital employed in the final product and its BOM parts



Individual areas are definite integrals of capital employed in BOM items for a physical unit of a particular final product and in the final product itself.

- F_{10} is CE in the final product No.10 during its storage
- P_0 is CE in the final manufactured part p_0, which upon completion becomes the final product
- P_1, P_2 are CEs in manufactured parts p_1, p_2, which are inputs of the final manufactured part p_0
- $M_{1.1}$ is CE in stored direct material $m_{1.1}$, which is input of manufactured part p_1
- $M_{2.1}$, $M_{2.2}$, $M_{2.3}$ are CEs in stored direct materials $m_{2.1}$, $m_{2.2}$, $m_{2.3}$, which are inputs of part p_2

The states of employed capital in the initial moments of storage of individual direct materials are identical with the direct material cost of products. Linearly increasing states of employed capital in the picture from the initial to the final moments of individual definite integrals simply display the growth of process costs for the relevant items during their storage or manufacturing. The state of the capital at the final moment of storing the final product, i.e., when selling it to the customer, is identical to product costs.

Costs and CE in phases of an operation

The figure on the previous page shows the growth of costs and CE during the processes for the individual parts of the BOM and for the final product itself. Growth of costs for individual items is linear, but growth rates are different. We have done this in order to give the reader the framework idea about the development of costs and current capital for a certain final product.
The actual development of costs during the processes on a specific part of the BOM has phases with different growth rates. In production planning, four phases are usually distinguished for each operation: Setup of a work center for the operation on the part, processing the part, transporting the part to the downstream work center, and waiting the part in the queue. The times are defined for the production lot of the part. The rate of cost growth per piece or other physical unit of a part is highest in the processing phase and lowest in the queue phase. The time per piece is usually shortest in the setup phase and longest in the queue phase. While the setup time is in fractions of a minute, the queuing time is usually in the hundreds of minutes. Such different times cannot be accurately graphed even for a single operation on a certain part of the BOM. The capital employed in a part is by far highest the queue phase, lower in the transport phase, very small in the processing phase, and almost negligible in the setup phase. The individual phases are described on the following pages.

Differences between traditional and lean manufacturing in graphic form

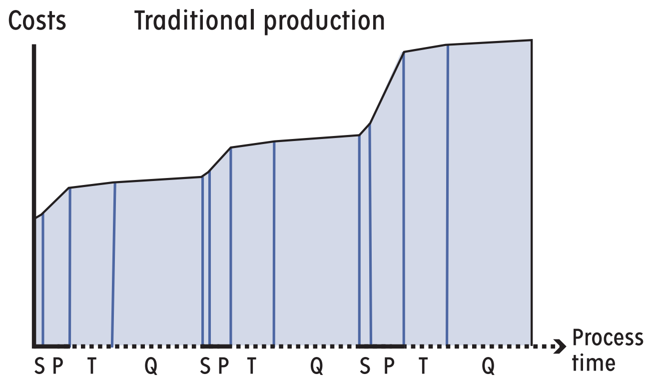
It is said that one picture can say more than 1000 words. This is undoubtedly true in the case of graphs of a definite integral, for instance when comparing the financial parameters of traditional and lean production with the charts on the right. These charts relate to three operations on a certain part of the BOM and
• the solid line on the x-axis characterizes the sections in real time
• the dotted line characterizes the sections whose real time is multiply longer
• the letter S is used for setup, P for processing, T for transport, Q for queue
The graphs simultaneously characterize the development of costs and CE during all three operations on the respective part and show almost three times lower CE in the process as well as significantly lower cost per part at the end of the process in lean manufacturing compared to traditional manufacturing.
However, these charts do not capture the fixed capital in the processes. The following page comments on this.

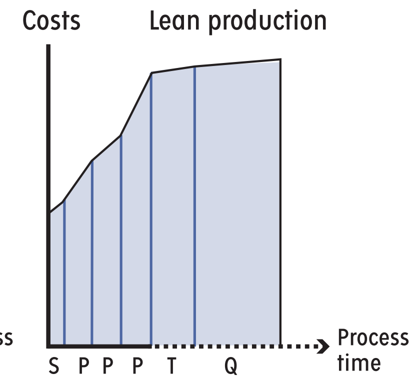
Effect of production lot on costs and CE in inventory for a unit of BOM part

A well-known problem is setting the lot size for individual parts of the BOM. The problem and its conceptual solution were first formulated in writing by Ford Harris in 1913. As the production lot increases, the setup cost per unit decreases, but the time and cost of the unit in inventory increase. The optimal lot, called the „economic order quantity - EOQ", is when the sum of these two cost components is the minimum. But the fundamental problem is the definition and measurement of „the cost of inventory". This usually means the so-called „cost of capital". However, that's a confusion of terms. As has been explained, the costs and CE are two quite different variables that need to be measured separately. That applies in general, i.e. also to manufactured parts in inventory. This is clearly illustrated by the graphs below.

Dependence of costs and CE of products on the types of processes

Costs and CE in processes for a certain product are very different in traditional and lean manufacturing. Within these production types, however, there are different systems of organization of production processes with differently determined production lots. These systems are:
• Make to stock, where finished parts are stored in intermediate warehouses
• Lot for lot, where only finished products are stored and gradually drawn from the warehouse
• Make to order, where lots of products are shipped to specific customers upon completion



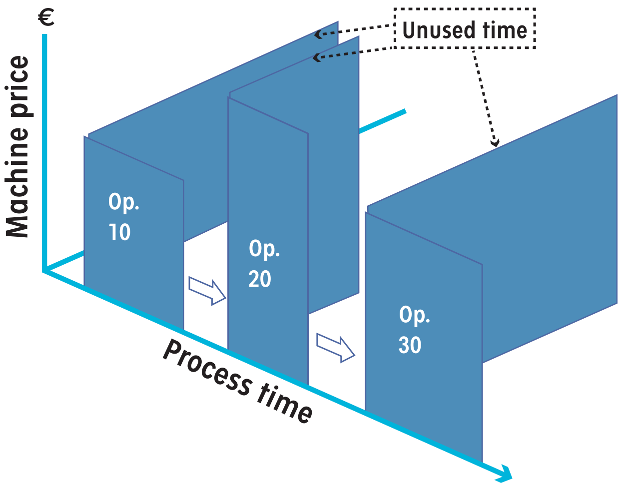


2. FINANCIAL Fixed Capital in Processing Phases of Manufacturing Operationss

Influence of time utilization of machines on employed fixed capital

The central activities of industrial enterprises are the processing phases of production operations, in which physical transformations of objects take place, from purchased materials to final products. Processing phase times are traditionally standardized. The key resources in these phases are people and production equipment esp. machines. Unlike people who do not materialize employed capital, machinery and other production equipment, together with buildings, form a crucial part of employed fixed capital. And the financial importance of machines continues to grow, not only in terms of capital employed, but also in terms of generation costs.

As already explained at the company-wide level, the time of capital employed in a certain period is determined by the calendar time. This also applies to capital employed in machinery and equipment. When quantifying employed capital in a certain machine in processing operations, only a part of the total calendar time is captured. In its important part, the machine is unused depending on the work regime of the enterprise, ie number of shifts, and often is partly unused within work shifts. Capital employed in the machine at the time of operations must therefore be increased by capital employed at a time when the relevant machine is unused. This is illustrated by a graph of these two components of definite integrals of the employed capital with the corresponding data in the table. PPROI calculates this data in given period automatically.



Period	Calendar time *Minute*	Part *No*	Operation *No*	Machine *No*	Machine price *€*	Process time per operation *Minute*	CE per operation *€Minute*	CE per operation *€Year*	Used time in period *Minute*	Unused time in period *Minute*	Utilization of calendar time	CE per operation in unused time *€Year*	CE per operation total *€Year*
1st quarter	129600	124	10	450	32 000	2	64000	0.122	36288	97 600	0.28	0.313	0.435
1st quarter	129600	124	20	328	55 000	1.2	66000	0.126	49248	74 600	0.38	0.205	0.331
1st quarter	129600	124	30	105	44 000	2.5	110000	0.209	41472	85 600	0.32	0.445	0.654

In cases where a certain machine processes several pieces of a given part or different parts concurrently during the operation, PPROI assigns to individual parts the corresponding shares of capital employed in the machine. In the same way PPROI proceeds when quantifying fixed capital employed in jigs, robots and other equipment directly operating in processing operations, and when calculating the spatial requirements of workplaces.
If there are several identical devices, PPROI considers their numbers. If in a certain period some facilities are completely unused, PPROI allocates their employed capital on other facilities in the same territory. Capital employed in the processes by products should be, and in PPROI is, always identical with the total capital employed in the enterprise.

Use of internal management prices, useful lives and depreciation of fixed capital items

Managers of numerous companies internally value machines and other equipment and sometimes also buildings in so called management prices, determine the economic life of items and then calculate their management depreciation. This is of great importance for ensuring the reproduction of fixed capital and permanently maintaining the competitiveness of the enterprise. The book prices of items registered in financial accounting usually underestimate the current value of items due to inflation and with a high degree of assets write-offs, depreciation does not ensure reproduction of capital. In such a situation, companies record accounting profits and pay taxes on them, but do not generate money for the timely renewal of machinery and equipment that would allow them to remain competitive. PPROI enables the records of fixed capital items at management prices as well as the calculation of management depreciation of items. When calculating ROI, PPROI works with half the values of management prices, which reflects the employed capital that the relevant items have in the middle of life. In parallel, PPROI also calculates ROI from book values of items. Managers thus see the financial situation comprehensively.

Entirely new financial information

Production machines and equipment not only contain employed capital, but also generate costs. In automated and robotic manufacturing, this is a crucial part of direct process costs. Although it seems incredible today, information on these costs does not exist in ERP. Industrial companies do not know these primary causes of their financial results and, already for this reason, they cannot be managed properly.
In PPROI, this necessary information is achieved by the unique architecture of the entire system that, compared to ERP, contain many new interlinked computer tables with many new variables and mathematical functions. Most of required input data in enterprises exists, but they are scattered in different kinds of documents in a way that does not allow their processing. It is needed to record them into the PPROI, whose unique calculation procedures result in new and correct information on both costs and CE in processes by products. The basis for obtaining this financial information is a completely new description of processing operations from a physical point of view. The operations are divided into microphases, in which the individual machines occur, and standard times are determined for the microphases.. This also applies to microphases of a manual nature, provided by operators and to microphases in which combinations of resources operate. This information is also necessary for the physical planning and management of lean manufacturing. The issue is described in III. part of this document - Physical. Now we outline the structure of product costs generated by machines.

Variable and fixed costs

Costs generated by machines include both variable and fixed costs. The majority of cost components, which must be calculated separately, are variable. And most of them are incured when the machines are active, not during the entire operation. These times are recorded for microphases of operations.

Part of variable costs is related to the activities of the machines themselves. These are mainly the cost of electricity, gas or other propellants, lubricants and maintenance costs. The second group of variable costs is generated by physical resources, which directly act on the manufactured objects, create their shapes and technical properties and connect parts of product into more complex units. This includes, e.g., dies and molds, cutting and grinding tools, liquids, cleaning agents and technical gases.

The most significant type of fixed cost is depreciation, which, like employed fixed capital, depends on the time utilization of the items in the period considered.
The columns for standard components of both variable and fixed costs are preset in PPROI, the user can select those that are relevant to his/her enterprise and add others.

Period	Part No.	Linked operations	Depreciation of machines €	Depreciation of tools & jigs €	Machine elecricity €	Machine gas €	Cuting tools €
Year	280012	10-40	1.82	0.28	2.46		3.58
Year	280012	50-70	0.94	0.11	1.32		0.95
Year	280012	80	1.08	0.08	0.42	2.68	
Year	280012	90-120	2.85	0.25	3.41	5.05	

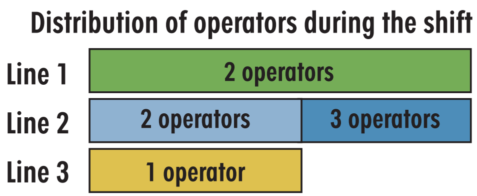
The table shows an example of the most important components of the planned machine costs in the production of 1 piece of metal part of BOM that goes through the processes of machining and heat forming. Data specified for linked operations in lean manufacturing are the sums of values defined for individual machines and equipment at work centers where operations take place. The cutting tools in the case described are drills.

The overall physical and financial management of cutting tools is enabled in PRROI by a specific module used by people responsible for this kind of the company's activities. E.g., the cost of a certain drill per 1 minute of drilling takes into account not only the purchase price of the drill and the time until it is blunt, but also the number of sharpenings of the drill during its life and the price of one sharpening in specialized firm.

Drill No.	Purchase price €	Time of one use *Minute*	Number of sharpening	Price of one sharpening €	Cost of 1 minute of driling €
0358	50	30	4	10	0.6

Rewarding teamwork in lean manufacturing

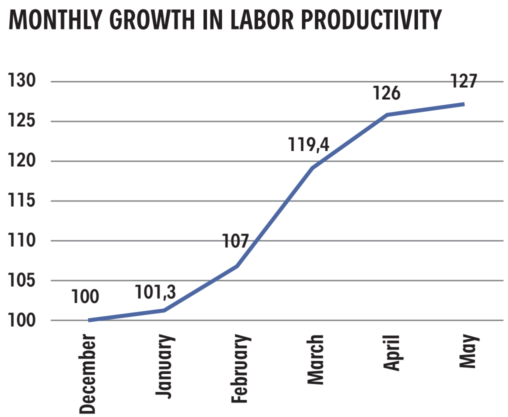
The Industrial Revolution of the 18th century gave birth to a deep division of labor and the remuneration of workers according to number of manufactured pieces at specialized workplaces. Scientific management of the early 20th century followed this by optimizing and standardizing manual work based on motion studies and rewarding individuals according to meeting time standards. Each operator reported its performance separately. Hourly wage rates varied for different types of work centers according to the complexity of the work. This is common so far.



In lean manufacturing, however, a particular operator serves different types of linked work centers, and the number of operators within a line may vary. As the time requirements for individual lines resulting from the production plan are different, in order to utilize the disposable time of operators some individuals need to work on multiple lines during a shift. The isolated work of individuals is replaced by teamwork.This places completely new demands not only on the standardization of work and production planning, but also on the remuneration of operators. Hourly wages do not solve the problem, as there is a lack of motivation on performance. PPROI for this progressive production contains an incentive pay system.

The building blocks of this module of PPROI are variant process standards for different numbers of operators in individual production lines, electronic registration of groups of specific operators on lines in certain sections of working time, the number of parts processed in these sections, and formula of dependence of operators‘ remuneration on meeting relevant variants of process standards. PPROI automatically allocates group results to individual operators, and the next day everyone can see how much they have earned in the previous shift. This leads to rapid growth of labor productivity, the benefits of which are shared by operators through their higher wages with a company through its higher profit.

Cited appreciation of the system by the CEO of the automotive enterprise relates to the pilot project implemented in one production hall, which was to be applied throughout the enterprise. However, the project was stopped after 5 months when concern headquarters decided to implement in all its enterprises a unified ERP. The lean production in the enterprise thus lost any information support.



„The PPROI information system has fully supported the introduction of lean manufacturing in one of the production halls, and has ensured its comprehensive management, from the setting of detailed process standards, via the creation of execution schedules, the interim records of reality in kiosks, daily reporting of fulfilment of schedule by teams and individuals to subsequent calculation of bonuses to operators. ***Our productivity after half a year*** *since PPROI implementations has* ***increased by 27%.***“

CEO, Enterprise of automotive industry

Comprehensive calculation of direct labor costs of products

In all the companies where we operated, we found that the calculated direct labor costs for the product portfolio in a given calendar year is tens of percent smaller than actual costs of the enterprise associated with direct production workers. There are two types of causes: nonfulfillment of work standards and underestimation of hourly wage rates for individual types of work centers. In order to eliminate the second cause, which devalues any costing of products, a module was introduced in PPROI that captures direct labor costs comprehensively and dynamically.

Operator No.	Production territory	Hourly cost components €		
		1	1 < i < n	n
001	11	10.5	2.4	0.6
002	16	9.0	2.2	0.7

HRM department records in PPROI for each operator all the planned components of hourly costs that the company must incur. The first component is the basic wage in the production territory in which the operator operates. The following are other cost items that enter the gross wages of employees, e.g., bonuses for meeting standards, for multi-operational skills, holiday pay and sickness. Gross wages are increased by the percentage paid by the company for social insurance. The last group consists of costs of work clothes and protective equipment, meal allowances, and other non - wage expenses that the company spends per particular worker. Sum of these values are divided by the coefficients of fulfilment of the time standards of labor, whose values are usually less than 1. The average of the total hourly costs per individual workers in a certain production territory determines the hourly labor costs in the relevant territory in the planned or previous period. These values change automatically in the planned periods when the basic components change.

Costs and CE in Setup Phase of Processing Operations

Content and significance of preparation of work centers and lines for processing operations

At the same work center, the same kind of processing operations are performed on different parts of the BOM, and sometimes more operations of the same kind on the same BOM part, for example, drilling holes in metal objects. The work center must be prepared for the perfect course of processing. In the case of drilling, it is necessary to attach a jig into which the part is clamped to the plate and ensure that in the processing phase each individual part is quickly and accurately positioned to the jig so that drilling takes place at the desired location. Before that, the jig used for the previous part of the BOM must be removed. This can be simplified by using jigs that are adaptable to place and hold various parts of BOM. The process phase, called setup, is included among the non-value-adding because it does not change the properties of the produced parts. In some contexts, such as the replacement of press dies, this phase was very time-consuming and costly. To minimize the time of this phase, an SMED system was created in the 1970s by Shigeo Shingo and marked as a revolution in manufacturing. The problem was then also reflected by the manufacturers of machines and tools. The setup phase has broader aspects and may relate only to the reorganization of workplaces, e.g., when changing BOM parts on assembly lines.

Calculation of costs and capital employed for the lot and unit of a certain BOM part

The setup activity and its time refer to the production lot (batch) of the respective part. Setup time per piece (or other unit of measure) of BOM part is inversely proportional to the size of the production lot. The impact of the production lot on the employed capital and costs of a certain operation on a certain BOM part in the setup phase separately and together with processing phase is illustrated in the table.

Production lot *Quantity*	Setup time per lot *Minute*	Setup time per unit *Minute*	Processing time per unit *Minute*	Total time per unit *Minute*	CE total in used time per unit *€Year*	Setup costs per unit *€*	Processing costs per unit *€*	Total costs per unit *€*
20	10	0.5	1	1.5	0.6	0.15	0.47	0.62
100	10	0.1	1	1.1	0.44	0.03	0.47	0.5
500	10	0.02	1	1.02	0.408	0.006	0.47	0.476
1000	10	0.01	1	1.01	0.404	0.003	0.47	0.473

When the size of the production lot increases then both capital employed in used time and costs per unit of BOM part in the setup phase of an operation decrease in proportion to the decrease in time per unit.
The effect of one minute of time per unit of BOM part in the setup phase and in the processing phase is the same only in the case of employed capital. The costs of one minute in the processing phase is higher than in the setup phase.
In the example, the cost of 1 minute of time in the setup phase = 0.15 * 2 = 0.30, while the cost of 1 minute of time in the processing phase = 0.47. This is because in the processing phase, machine variable costs (described on page 2-–5) arise, while in the setup phase only labor costs and fixed costs are incurred. From a certain production lot size, its further increase has a negligible effect on the total costs of the operation, which in the table illustrates the increase of the lot from 500 to 1000 pieces.

If we extract from the scrap due defects in processes (more on page 2–8), the lot size of a certain part is the same for all operations on the respective part. However, if there are several identical machines at a given work center, it may be advantageous to split the lot into two or more machines. This is especially the case in lean production, if the processing time of a certain operation on one machine is too long compared to other operations in the line and significantly reduces the performance of the entire line. In proportion to the number of machines into which the lot is split, the costs and employed capital in the setup phase increase and is reflected in PPROI.
The procedure for calculating values of financial variables in the setup phase is the same as in the microphase of the processing phase of the operation, in which the operator operates a machine that is inactive as is usually the case of removing and inserting parts into the machine. The only difference is in the calculation of labor costs if the setup phase is provided by specialized adjusters, because the wage level of adjusters is usually higher than for operators and adjusters are paid per hour regardless of performance; so, their labor costs are fixed. PPROI therefore calculates the time utilization of the adjusters in the planned period and increases the costs calculated for the setup times by the costs incurred at the time when the adjusters are not utilized.
The setup phase of work centers in PPROI also includes the time during which the work center is preparing to go into standby mode; e.g., heating furnaces before the start of shifts. Its costs per unit of products produced can be very significant.

Multilateral financial impacts of quality

The term quality is associated with the term defect. Quality inspection of finished products (pictured) deals with the detection of defective products, their separation from products without defects, for defective products by discarding unrepairable products (scrap) and for repairable products, identification of types of defects. It is also important to identify work centers where defects arose. Quality checks also take place within individual production operations. The activities of people providing the inspection and the control equipment generate costs, included in the theory into term „Cost of quality". This also includes costs incurred in quality management department. However, the basic component of quality costs, which must be quantified primarily, are production costs generated by defects themselves. And these costs must be included in the direct production costs of individual products. In PPROI, all the above activities related to quality are recorded separately and financially reflected in the direct or indirect costs of processes according to products. This also applies to employed capital. Indirect costs and CE related to the quality management department are allocated to processes by products according to the procedures outlined on page 2–10.

Projection of standard defects of operations into direct costs and CE in processes by products

The basis of systematic quality management lies in the registration of defects and in the subsequent determination of defect standards in individual operations on parts of the BOM. In PPROI the defect standards in the setup and processing phases of individual operations are registered separately, both for defects repairable and non-repairable. These values are projected into the calculations of costs and CE of the planned products as well as into the physical production plans.
The described procedure was developed in PPROI because ignoring defects leads to significant undervaluation of the true direct costs of products. Repairable defects draw on the capacities of workers and machinery and increase costs and CE compared to operations without defects because it is necessary to perform additional works for the operation in which the defect occurred. Non-repairable defects are much more serious as they lead to the scrapping of used materials and devaluation of the results of work in given and previous operations on the manufactured part and in all lower BOM parts. All costs and CE must be spent repeatedly from the beginning of the production.
An example of PPROI procedure in calculating the direct production costs of a certain final product, respecting standards of non-reparable defects in individual operations on parts of the BOM for the relevant product in the tables links to the diagram of processes on manufactured parts P_0, P_1, P_2 on page 2–2. Operations and their parameters are now additionally defined.
From the standard share of non-reparable defects in the processing phase of individual operations, the coefficients of increase in the number of operations are calculated in comparison with production without irreparable defects, in which the values = 1. In proportion to the values of these coefficients, it is necessary to increase the production lots of BOM parts in individual operations in order to finally create the planned production of final product. In proportion to the coefficients, the direct labor and variable machine costs also increase compared to defect-free production.

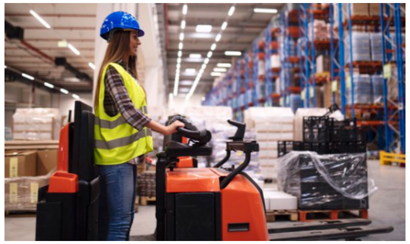
Part	Operation	Non-repairable defects *Share*	Increased number of operations Coefficient	Basic labour & machine costs €	Increased labour & machine costs €	Labour & machine costs of quality €
P_0	10	0.0051	1.0223	0.654	0.669	0.015
P_0	20	0.0055	1.0171	1.381	1.405	0.024
P_0	30	0.0038	1.0115	1.020	1.032	0.012
P_0	40	0.0076	1.0077	1.140	1.149	0.009
P_1	10	0.0041	1.0477	0.968	1.014	0.046
P_1	20	0.0032	1.0434	0.772	0.806	0.034
P_1	30	0.0038	1.0401	1.126	1.171	0.045
P_1	40	0.0059	1.0361	1.332	1.380	0.048
P_1	50	0.0021	1.0300	0.724	0.746	0.022
P_1	60	0.0054	1.0279	0.986	1.013	0.027
P_2	10	0.0036	1.0523	0.956	1.006	0.050
P_2	20	0.0068	1.0485	0.991	1.039	0.048
P_2	30	0.0059	1.0414	1.275	1.328	0.053
P_2	40	0.0077	1.0352	1.423	1.473	0.050
P_2	50	0.0048	1.0272	0.886	0.910	0.024
Total				**15.634**	**16.141**	**0.507**

The costs of direct materials increase in proportion to the coefficients of increases in the first operations on parts P_1, P_2, as the materials enter these operations. The difference between the increased production costs due to non-reparable defects and the costs of defect-free production results in direct labor & machine costs of quality. These costs, in the example = 0.507 + 0.641 = 1.148 €, mean an increase in costs by 4.07% compared to defect-free production and are very significant. Reducing the standard defects of production operations leads to a reduction of all other components of costs and CE related to quality and notably increases profit and ROI of the enterprise.

Direct materials	Input to the part	Basic costs €	Increased costs €	Cost of quality €
$M_{1,1}$	P_1	3.41	3.573	0.163
$M_{2,1}$, $M_{2,2}$, $M_{2,3}$	P_2	9.14	9.618	0.478
Total		**12.55**	**13.191**	**0.641**

2. FINANCIAL Cost and CE of Logistics Processes by Products

Specifics of logistics processes and the need for separate calculations of their financial parameters



The processes on the purchased direct materials for a given final product and on the finished product itself are exclusively logistics. They have the general characteristics of logistics processes in any warehouses. And even the manufactured parts, before the final product is completed, spend most of their time in logistics phases in production halls and potentially in intermediate warehouses. During the logistics processes, items are handled, transported and stand in inventories. In ERP, these processes are completely ignored. In general, the costs of direct logistics processes are included in indirect costs or into overheads derived from direct wages in processing operations or also from costs of direct materials. However, this is nonsense, because the monetary value of any item is not a factor of its logistics costs. The solution consists in the description of logistics processes for individual items and calculations of their costs and capital employed. We haven't found anything similar even outside of ERP. The PPROI procedures outlined below are original and applicable for the financial parameterization of logistics processes in general, not only in industrial companies.

PPROI procedures in calculation of costs and employed capital in logistics processes by products

Compared to processing operations logistics processes are simple and not demanding on machines and equipment. These are mainly forklifts and racks. Employed capital in these resources is relatively low, the machine costs only include depreciation, cost of electricity and maintenance. The objects for which the times and resources of the processes are primarily determined, and the financial parameters calculated, are transport lot (T lot) and „stock keeping unit" (SKU), which is used in handling and storing of items. One SKU usually contains more pieces or other units of measure of purchased materials, manufactured parts, and final products; one T lot usually contains more SKUs. In both cases the sessions can be one-to-one and in the case of products that the customer assembles himself, e.g., furniture, one piece of the final product contains more different SKUs. From the values of costs and employed capital calculated for the T lot and for the SKU the values for one piece or for another unit of measure of the relevant item are determined.

The calculation of costs and employed capital for logistics processes on a certain final product in the finished goods warehouse is illustrated by the data in the tables. The first step is to determine the number of pieces in the SKU and the number of SKUs in the T lot.

Final product No	Number of pieces in SKU	Number of SKUs in T lot
174	4	6

Process Phase	Unit of measure	Time *Minute*	Labour costs €	Machine costs €	Space costs €	Total costs €	Total cost per piece €	CE in machine *€Minute*	CE in space *€Minute*	CE total *€Minute*	CE total per piece *€Minute*
Loading at output of manufacturing	SKU	0,5	0.125	0.0025	0.02	0.1475	0.0369	7500	3000	10500	2625
Transport	T Lot	5	0.5	0.1	0.2	1.8	0.075	75000	30000	10500	4375
Unloading for storage	SKU	1	0.25	0.005	0.03	0.285	0.0712	15000	6000	21000	5250
Removal for storage	SKU	1	0.25	0.005	0.03	0.285	0.0712	15000	6000	21000	5250
Transport	T Lot	5	1.5	0.1	0.2	1.8	0.075	75000	30000	105000	4375
Unloading for shipment	SKU	1	0.25	0.005	0.02	0.275	0.0688	15000	6000	21000	5250
Return of empty forklift	T Lot	4	1.25	0.07	0.16	1.48	0.0617	60000	34000	84000	3500
Total							0.4598				30625

Labor and machine costs are calculated in the same way as in their calculations in processing operations. Capital employed in machinery is also calculated in the same way.
Space cost and CE in space per 1 piece of the product are calculated by the allocation method. The allocation key is the time that objects spend in processes. The fixed space costs in the evaluated period for the area intended for transports are multiplied by the ratio of the transport time of one T lot of a certain product to the sum of the times of all T lots of all products in the period. The result are space costs for one T lot of the respective product. Dividing this value by the number of pieces in one T lot results in space costs per piece. The cost per unit therefore depends on the portfolio of the products transported. As the number of transports increases, the cost per piece decrease.. The procedure is similar in calculations of space costs for handling and storing; in this case the cost of 1 SKU is determined in the first step. Space CE is allocated in the same way as space costs. Capital employed in the product itself in inventories is calculated separately according to the cost of the product and its time in inventories.

2. FINANCIAL Indirect and Total Costs and CE in Processes by Products

Truly indirect values of financial variables and their allocation on direct processes by product

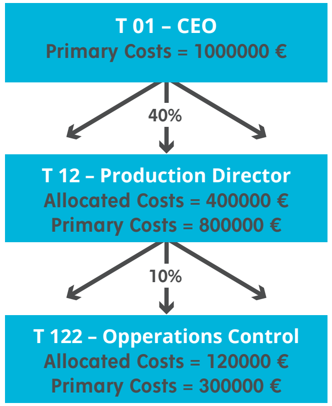
In the previous four pages, we have outlined the procedures of PPROI's calculations of costs and capital employed (CE) generated by individual resources in direct processes by product. The traditional restriction of direct costs to direct material and direct wages, because information on other direct costs is lacking, is confusing and the inclusion of all other costs into several black boxes of the overheads overshadows and distorts reality. The situation is even worse due ignoring CE. However, a significant part of the enterprise resources exists and generates costs outside the direct processes. These truly indirect costs, usually included in administrative overheads, are defined in the PPROI for specific resources, as in the case of direct costs. This also applies to CE. Subsequently, these values are appropriately allocated to items of direct processes and the sum of direct and indirect values results in total costs and CE for individual items. Follow-up aggregations of these values according to BOM result in the total costs and CE in processes by products. PPROI provides all calculations automatically according to internal math formulas.

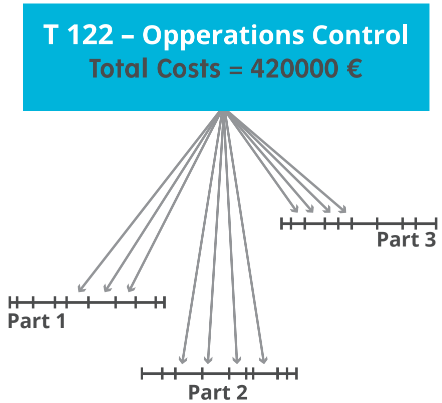
Definition, links and financial parameters of enterprise territories

The enterprise is divided into parts called territories. The territories in which direct processes by products take place are direct, other territories are indirect. The structuring of both types of territories is multilevel.
Direct territories main structure: (1) Material supply; (2) Manufacturing; (3) Sales. This structure corresponds to the sequence of already described phases of direct processes on direct materials, manufactured BOM parts and on finished products. These main territories are divided into sub-territories, such as „production centers" within Manufacturing.
Indirect territories are recorded from two aspects: Physical territories as registered parts of buildings, i.e., offices, communication, social and other delimited spaces. Their annual space costs and CE are determined by facility management principles. PPROI contains tables with fields for the required records. Financial territories in principle reflect the organizational structure of the enterprise. For them, the annual personal costs and costs of purchased materials and services are taken over from the budgets of the company's departments; in PPROI they are structured and can be supplemented. Spatial financial parameters of financial territories are derived from the spatial parameters of physical territories and the number of employees of individual financial territories with permanent workplaces in physical territories.

Allocation procedures

Depending on the tightness of the relationship of indirect territories to direct processes, allocation proceeds in two ways:
(a) **Application of the allocation pyramid** is used first when the relationship of indirect territory to direct processes takes place through other indirect territories. The values of costs and CE of the given territory are dissolved to values of lower territories up to territories closely related to direct processes. At the higher territory, the share of costs and CE devoted to the lower territory are determined by an expert estimate. The system increases values of both variables primarily registered for lower territories by allocated amounts (see the first diagram).
(b) **Direct allocation** is used when the indirect territory directly supports some phases of direct processes. As allocation keys are used the values of variables in direct processes, which are appropriate for characterizing these relations. E.g., when allocating costs and CE in the indirect territory „Operations Control" focused on manufacturing processes in particular production centers, the values of the indirect territory are allocated only to operations on BOM parts realized within controlled production centers and the labor time of operations is used as an allocation key. This is illustrated by the arrows in the second diagram. A specific type of direct allocation is used when the indirect territory to direct processes has not a close relationship, but the application of an allocation pyramid is inappropriate.
Types of indirect territories, their relations to the phases of direct processes and allocation keys are preset in PPROI.





PPROI calculations respond to any changes in input data in indirect territories as well as to changes in direct process standards and to the product portfolio in the period under review. The system also automatically recalculates the annual values defined for indirect territories for a shorter periods of the operational plan and then calculates the costs and CE for products in these periods.

2. FINANCIAL Principal Change of Product Pricing

When balancing costs and CE to maximize ROI we assumed the existence of product prices. However, these prices are not a priori given. In the first step, they are calculated by the personnel of enterprises in which the products are finalized and the subject of sale to cover the costs of products and ensure the required profit. This traditional procedure involves two types of problems: (1) The principle of determining the profit margin, (2) Different and generally incorrect calculations of product costs. PPROI solves both of these problems.

Before PPROI

Basic formula: **Product price = Product cost * (1 + (Profit / Cost)** *target*

The calculated product price is a result of the product cost and setting the target value of profit-to-cost ratio, i.e., cost efficiency. This formula clearly reflects the traditional thinking that the profit for a product should be proportional to its cost. We have previously commented on the incorrectness of this thinking and the contradictions to which it leads. Now we illustrate the contradictions of standard product pricing.

Assume a target value of the profit-to-cost ratio = 0.12. In table 1 which characterizes the manufacturing of product B in the chain of enterprises 1 and 2, the calculated price of product B = 405. This price is much higher than the price of product B = 380,8 when it is manufactured in the enterprise 3, where item A does not exist as a product; here it is a semi-finished product (see table 2). The price difference = 405-388.8 = 24.2 is due to the calculation of the profit in enterprise 2 from the value 201.6, which is the price of product A transferred from enterprise1 to enterprise 2, where this value forms the part of direct material costs. The profit for item A is thus calculated twice, once from the costs of item A in enterprise 1 and the second time from its price in enterprise 2, without any physical change of this item or for any other logical reason. These duplicate profit calculations do not occur in the manufacturing of item A in enterprise 3.

Table 1

Enterprise	Product	Target Profit/Costs €/€	Direct material costs €	Process costs €	Total costs €	Price €	Profit €
1	A	0.12	100	80	180	180*1.12=201.6	21.6
2	B	0.12	201.6+90=291.6	70	361.6	361.6*1.12=405	43.4

Table 2

Enterprise	Product	Target Profit/Costs €/€	Direct material costs €	Process costs €	Total costs €	Price €	Profit €
3	B	0.12	100+90=190	80+70=150	340	340*1.12=380.8	40.8

In PPROI

Basic formula: **Product price = Product cost + Product CE * ROI** *target*

The pricing formula respects the basic financial principle, i.e., the proportionality of profit to the capital employed and arises by modifying the basic equation ROI = (Price - Cost) / CE. Product price in the pricing formula is determined by the product cost, CE in the processes for the product and the target value of ROI.
There are no duplicate profit calculations from the same value in supply chain of enterprises. Profit is calculated from CE, the values of which in various enterprises have no intersection, mathematically they are disjunct sets. In the example (table 3) there is no intersection between the values of CE = 100 in enterprises 1 and 2. The calculated price of the product B = 364 is the same as its price if it is produced in the enterprise 3 (see table 4).
However, this is so if the manufacturing the given product in supply chain of enterprises has the same requirements on resources as its manufacturing within one enterprise and if we abstract from the financial demands of transport between enterprises 1 and 2.

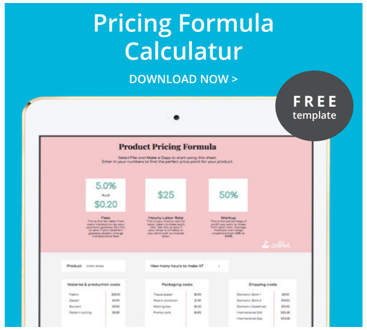
Table 3

Enterprise	Product	Target ROI €/€Year	Total costs €	CE €Year	Price €	Profit €
1	A	0.12	180	100	180+100*0.12=192	12
2	B	0.12	192+90+70=352	100	352+100*0.12=364	12

Table 4

Enterprise	Product	Target ROI €/€Year	Total costs €	CE €Year	Price €	Profit €
3	A	0.12	190+150=340	200	340+200*0.12=364	24

Growing chaos in product costing in connection with product pricing



For product pricing, calculators are currently available free of charge on the Internet. The calculation is based on the traditional principle, which we characterized on the previous page by the formula Product price = Product cost * (1 + (Profit / Cost) *target*. The user enters the cost components and the required value of the profit to cost ratio and the calculator calculates the price online. The cost components are named unconventionally and differently in different calculators. The problem is the content and completeness of individual components of costs and especially the determination of their values. E.g. in the calculator in the picture (Zibbet) one of the cost components is called „Costs associated with the use of equipment“. However, there is no prescription for calculating the value of this component, not only within the calculator, but also in management accounting, and this component of costs does not occur in ERP either. The complexity of the problem of determining the value of this cost component and its solution in PPROI we expressed in connection with the calculation of processing costs generated by machines (p.2–5). Thus, the simple price calculators not only do not solve the problem of correct product pricing, but only further complicate the traditional problems of product costing.
Different methods of product costing are multiplying and spreading in connection with pricing also in other contexts, inter alia in connection with price negotiations of enterprises in the supply chain. Due to unsatisfactory methods of cost calculations in the theory of management accounting and ERP, individual companies create their own calculation procedures using Excel. In large corporations, these procedures, originated in the central financial controlling departments, are binding on all enterprises of given corporation and potential suppliers of these enterprises are often obliged to prove the costs of the products offered according to the prescribed calculation formulas by customers. As we have found out in practice, prescribed formulas by different corporations vary and lead to different costs of certain products. The correctness of the individual formulas is therefore mutually exclusive and sellers offering the same product to different customers are confused which cost calculation to believe. This is more so as their own cost calculation formulas lead to different results.
Proving the costs of suppliers to potential buyers should serve to justify the required prices. In the price offers of different suppliers of the same product, suppliers with lower costs are preferred. And that is the main problem. As already explained, suppliers with higher cost of certain product may have significantly lower employed capital and higher ROI in the manufacturing of the product concerned and may therefore reasonably offer a lower price than suppliers with lower product costs. However, only a few people realized that before PPROI and no one could prove it.

More on product pricing in PPROI

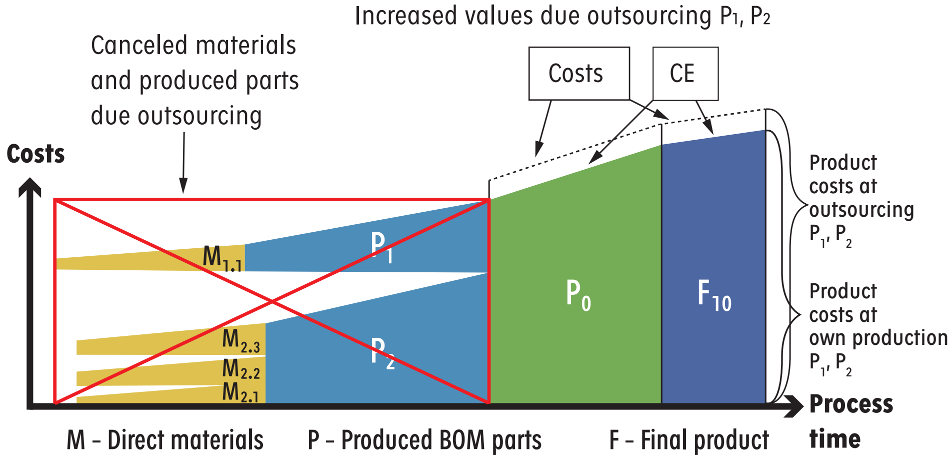
The accuracy of costs and CE calculations in PPROI is enabled by the completely new basic structures of the information system, new variables and their mathematical functions. As a significant part of the costs and the highly prevalent share of CE are fixed, the values of financial variables for the individual products depend on the product portfolio in the period considered. In PPROI, the portfolio of products in the annual plan is decisive for the product pricing. Nothing, however, is rigid. In order to continuously determine the prices of new products in the annual outlook, the period of the annual plan is rolling, and the actual parameters of products, processes and resources are projected into the calculations. PPROI responds to continuous improvements and other changes. Sellers take advantage of this PPROI potential almost every day. The calculated prices are, of course, only indicative. If sellers believe that it is possible to increase them without jeopardizing the marketability of products, they are not limited from above. Significantly lower prices compared to those calculated for the target ROI value should be justified to the financial department. The positive effect on prices and the associated overall financial results of the enterprise has the financial motivation of sellers on the ratios of actual prices to the target prices.
In price negotiations with customers, they are always positively surprised by the precise cost calculations of products in PPROI, especially the machine cost for microphases of operations. This also inspires confidence in the need and accuracy of CE and ROI calculations for individual products, even if customers encounter these variables for the first time and ask for an explanation. Thus, the unique financial calculations of costs, CE and ROI according to products and the subsequent product pricing in PPROI usually not only do not create problems in price negotiations but, on the contrary, open the eyes of customers, which they appreciate.

Influence of interfirm cooperation on the values of financial variables and decisive role of ROI

Each business entity cooperates with some of others and the forms and intensity of co-operation of different firms are different, changing and dependent on decisions made by people. Thus, the basic question of strategic decision-making expressed by the words „Make-or-Buy?“ is which activities an enterprise in creation of its product should provide by its own resources and what to buy from other enterprises, which is currently called outsourcing. The criterion for this decision should be the ROI of alternatives. The most important form of cooperation of industrial enterprises is sales and purchases of manufactured items in downstream enterprises in the supply chain, which we paid attention to on page 2–11. The examples were designed to clearly demonstrate the incorrectness of the traditional evaluation and pricing of products according to costs and cost efficiency (or profitability) and the rationality of the application of ROI. In the example on page 2–11, the ROI values for product B were the same in enterprises 2 and 3, even though enterprise 2 bought item A from enterprise 1, while enterprise 3 manufactured item A in-house. The different values of costs and CE in the alternatives were fully compensated in the value of ROI. However, this is the situation when the alternatives have the same resource requirements. But this is generally not the case. In order to make the right Make-or-Buy decision, it is necessary to calculate costs, CE and consequently ROI of alternatives.

Graphic illustration of the financial consequences of outsourcing

To graphically clarify an impact of outsourcing on CE and costs of given product, we follow the graph on page 2–2. Instead of manufacturing parts P_1, P_2, these are purchased and only P_0 is manufactured within the assessed enterprise. In this case the CE in inventories of purchased materials $M_{1.1}$, $M_{2.1}$, $M_{2.2}$, $M_{2.3}$ and in originally manufactured parts P_1, P_2 does not exist. Instead, the CE is in inventories of parts P_1, P_2 which are the direct materials. This CE (not shown in the figure) must be calculated. The higher costs of the purchased parts compared to the costs of their own production are expressed in the figure by the dashed line from the start of production of part P_0 to the dispatch of the final product F_{10}. The area between this line and the original CE represents the increase of CE in part P_0 and in the final product F_{10} due to outsourcing of parts P_1, P_2. The biggest financial savings of outsourcing (not shown in the figure) are in the elimination of fixed CE in machines, other production equipment and in the space of production halls used originally for the production of P_1, P_2 parts. So, the overall CE after outsourcing should drop dramatically. In contrast, the costs of the product, identical to the states of CE in the product F_{10} when it is sold, are higher after outsourcing. These costs are characterized by abscissas on the right side of the figure.

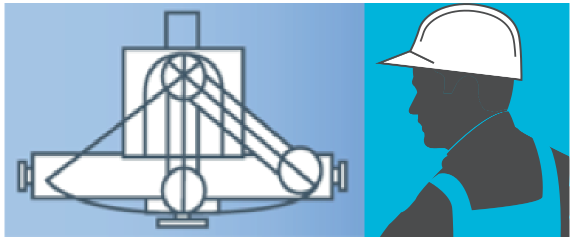


In general, however, a decrease in product costs due to outsourcing cannot be ruled out. The supplier can produce the relevant components much more efficiently compared to their manufacturing within the enterprise finalizing the product, among other things due to the economics of the scale of production of components and the better time utilization of expensive machines. On the other hand, existing outsourcing can be too expensive, e.g., due to the transport costs of items between remote enterprises. Replacing outsourcing with in-house production, which we have seen in some companies, leads to a smooth processing flow, especially when applying lean manufacturing. But fixed CE is growing, and ROI must therefore be calculated in this context as well.

Wider aspects of interfirm cooperation

Conflict between costs and CE exists not only when deciding between own production and purchase of parts of final products, but also in other forms of cooperation of enterprises. An example is the maintenance of machines either by the enterprise‘s own maintenance department or by external services. In internal maintenance, CE is necessary in the space, equipment and spare parts of the maintenance department, an external maintenance generates only cost of bought services, usually higher than the cost of internal maintenance. Both types of maintenance mostly exist in manufacturing enterprises simultaneously. In PPROI they are registered separately and separately projected into costs, CE and ROI of processes by products.

People and machines as complementary or alternative process drivers in PPROI



Processing, logistics and also administrative processes are driven by activities of people and / or machines (in the broad sense of the term machine). The relationship between people and machines in processes can be different. People and machines can work independently in certain phases of processes; this is the case of only manual work of people or automatic processing of objects and their handling of by machines. When people and machines ensure the process together, there are two alternatives: (1) Both people and machines are active e.g., in sewing clothes and transporting objects; (2) Active are only people and machines are in standby mode, which is e.g., the case of activities of people in the setup phase of the operation or inserting and clamping objects into machines before automatic processing and release and removal of objects after processing. At present, there is also a common phase in which two machines work together, one of which is active and the other passive; e.g., when robot inserts / removes object into / from processing machines. Each of these phases of processes has different financial consequences and it is therefore necessary to record people and specific machines in these phases and the time of each phase. This is the case in PPROI. In contrast, in ERP, only the total times of the setup and processing phases of individual operations and for them the number of people (or their times) are recorded. This disregard machines in enterprise IS we have already labeled in the Foreword to this document as the greatest paradox of our time. Getting the right financial information on enterprise resources, processes and products from ERP is therefore impossible.

Influence of people and machines on financial variables

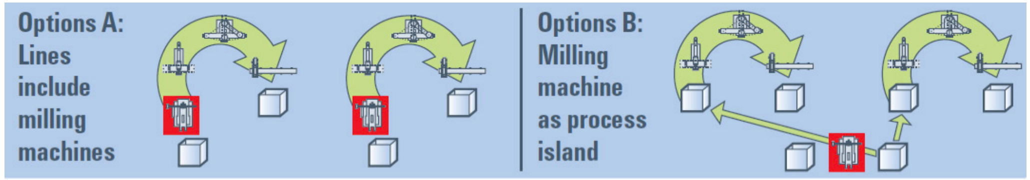
The financial demands of processes both on people and on machines are reflected in costs and subsequently in CE in stocks of materials, manufactured parts and final products, i.e., the enterprise's current (working) CE. The value of machines in itself (unlike humans) represents employed fixed capital. If the information system does not contain information on CE and the financial demands of the processes on resources are measured only in terms of costs, the real impact of machines on the company's financial results is deeply undervalued. This applies both to the financial evaluation of the existing situation and to deciding whether and to what extent to replace people's work with machines. There is also a significant difference between people and machines in terms of cost generation. While people generate costs only in their working time machines generate fixed costs in the form of depreciation in calendar time. The low time utilization of machines and the variable costs generated by machines can often lead to higher total costs of a given process after human substitution by a machine than before substitution. An important factor of the economically optimal proportion between machines and people is also the level of wages.

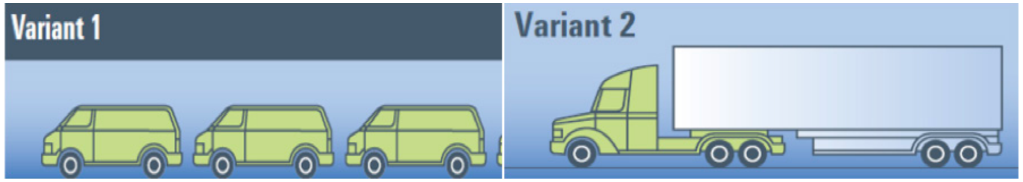
Robotization efficiency

The most advanced form of substituting human work with machines is robotization. The first step before deciding whether robotics pays off should be to make full utilization of people in manual work. We will therefore use the example of lean manufacturing from a book „Kanban; Just-in-Time at Toyota". This classic from 1985 is relevant even today. In the example, one operator operates 9 machines in a line, where he removes parts after their automatic processing and clamps new ones. This exchange on 1 machine is on average 8 sec. Tact time of production derived from demand is 113 sec. In robotics would be needed for each automatic machine include a robot, i.e., a total of 9 robots.
Assume the price of 1 robot is € 100,000 with a lifespan of 8 years. Then annual depreciation = € 12500. Next, assume 2 shift work schedule of 850 minutes per day on weekdays of the year which are 250. Then the operating time of 1 robot per day is (8/113) * 850 = 59.65 minutes and annually 59.65 * 250 = 14912 minutes. 1 minute operation of the robot therefore cost in depreciation 12500/14912 = € 0,838. One hour of robot operation costs € 50.3. This is significantly more than the full hourly labor cost per operator in most countries of the world. So robotization can't pay off. This is all the more so as its costs would include, in addition to depreciation, the costs of energy and maintenance of the robot. The reason for the inefficiency of robotization in the example is the low time usage of the robot compared to the use of the operator. 1 robot replaces only 1/9 of the work of one operator. With much better ratio in favor of the robot, robotization can be effective. It is always necessary to make sure that robotics saves not only the work of operators, but also their number, i.e., does not lead to their lower time utilization. In PPROI, robotics of processes is automatically reflected in the ROI of the respective processes according to the products as well as in the ROI of the enterprise.

Optimization of any types of physical solutions according to ROI

On the previous two pages, we paid attention to the main types of strategic decision-making in the enterprise: cooperation with other companies and the basic structure of resources in enterprise processes. However, ROI is a criterion of alternatives in all other types of decision-making. This also applies to lean production where is the basic question which work centers to include in the individual lines. If the sequence of processes on the individual parts of the BOM differs significantly, creating too long lines specific to different parts would lead to low machine time usage. Fixed capital and depreciation increase. Even with lower stocks of work in process and lower variable processing and logistics costs of production, total employed capital and / or total production costs could increase. The first image illustrates the problem: When one machine is enough to supply two lines, should it work alone, or should two identical machines be included in the two lines? Another type of decision-making is the frequency of material deliveries: Variant 1 in the second figure leads to lower material stocks, but variant 2 is usually cheaper in terms of delivery costs. The decision between options should be determined by ROI value.





PPROI version for hypothetical calculations

The value of an enterprise ROI is the result of the combined action of all its factors. The effect of a particular factor on the ROI value always depends on the specific configuration of the other factors. This fact must be respected by the information system if the calculations of ROI values are to be realistic. All variables must be integrated by mathematical functions in one information system, so that the influence of the value of a certain variable is reflected in the enterprise value of ROI in relation to the values of other variables in the period under review. It has already been emphasized in the previous text that this is a basic conceptual feature of PPROI that behaves like a living system - an enterprise organism.

In order to evaluate alternatives according to ROI before managers decide to implement some of them, PPROI contains the hypothetical version with current data of which those that are the subject of the evaluated alternatives are entered as new and replace the corresponding existing data. Calculations of ROI values from partially new data take place after they have been started by the user. Based on the resulting ROI values, the user selects the most effective alternatives and, when their practical implementation, records the relevant input data into the basic version of PPROI, which is binding for management.

Trade-off free situations and continuous improvement

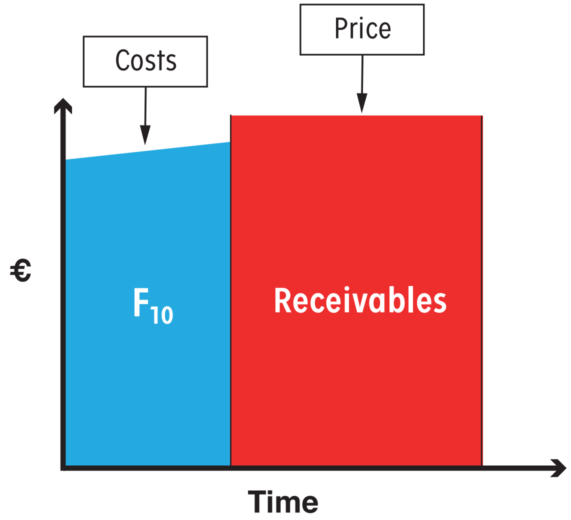
The opposite evaluation of alternatives in terms of costs and CE, which occurs in the basic types of strategic decision-making commented in previous pages, may not occur in general. In continuous improvement, trade-off free situations usually occur, where the reduction of costs leads not only to a reduction in current capital, but also to a reduction in fixed capital in its active time. This applies, among other things, to shortening process times and defects in processing of BOM parts in ways that do not require investment in production equipment. However, it can also be minor modifications of machines and production equipment, which lead to a reduction in the consumption of energy or technical gases, liquids and masses. These are reflected in the reduction of costs and CE of all products whose processes pass through the relevant equipment. Different types of savings in indirect territories are also significant. To objectively assess the financial benefits of improvement, it is useful to calculate new ROI values.

Product portfolio

The quantity and structure of products in the assessed period has a fundamental influence on the values of ROI of the enterprise as well as on the values of ROI in processes for individual products. Even in this case may be important decision making between alternatives enabled by a hypothetical version of ROI..

ROI, receivables and payables

When calculating ROI in processes for individual products, PPROI records the processes, their costs and CE from the moments of acquisition of direct materials for a certain product according to BOM until the moment of sale of the respective products. In the processes defined in this way, there is a real reproduction of capital, an increase in its value. CE in these processes is contained in physical objects. However, when calculating ROI values at company-wide level, receivables are usually also included in CE. This was already the case of the original pyramid of financial ratios designed by Donaldson Brown at Du Pont. The measurement of CE in receivables for a certain product is not a problem in PPROI as it is a definite integral determined by the price of the product and the time of the receivables. In relation to the CE in the inventories of the product F_{10} and its costs in the chart on page 2–2, the receivables are expressed in the following figure.



Receivables are not included into CE in the PPROI for two logical reasons:

1. Receivables of the seller enterprise represent in the buyer enterprise the direct material or other physical form of CE, from which the return is required. Thus, if receivables are included in the CE there are duplications (mathematically the intersections) of the same financial values of CE in enterprises at the supply chain and the true ROI values are underestimated depending on the size of receivables. Receivables do not represent any real capital that can generate income; receivables in fact represent free funding of CE operating in the purchasing enterprise by the enterprise selling the product.

2. It is illogical to reflect receivables and ignore payables, as receivables from the point of view of selling enterprises are the payables from the point of view of buying enterprises. Every enterprise is both a seller and a buyer, and if it funds the operating CE of customers free of charge, its own operating CE, on the other hand, is funded free of charge by the suppliers in the amount of his payables. From a supra-enterprise point of view, receivables and payables compensate, so the changes in receivables resembles a zero-effect game in which some enterprises gain, others lose. For individual enterprises, the care of receivables and payables is important, but it should be separated from the management of real processes by products in order to maximize ROI.

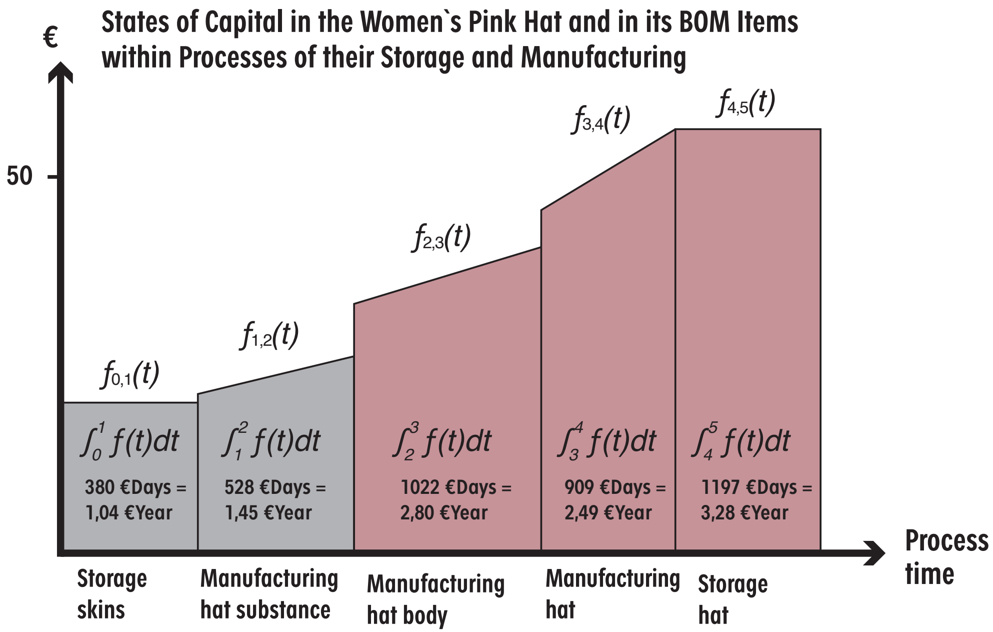
Funding the operating capital by loans

The capital operating in certain enterprise can be (partially or even fully) funded by external subjects, inter alia by banks, which require a return on the funds provided to the enterprise. Whether and to what extent the operating capital is financed by debt has no influence on the key importance of maximizing the ROI in real processes by products and on the PPROI procedures described on the previous pages. However, attention must be paid to the size of loans and the difference between the ROI value in enterprise processes and the interest rate from the loan (marked further by the symbol p). The consequences of both are quantified by the formula Yield = Loan * (ROI – p), which expresses the enterprise yield from the processes realized thanks to the loan in comparison with the situation if the enterprise do not realize these processes. If the ROI < p, the debt-funded enterprise processes result in an absolute enterprise loss.

The ROI values in the processes for individual products are also comparable with the interest rate on the loan. If the ROI values in processes for some products are significantly lower than the interest rate on the loan, it is necessary to assess whether it makes sense to produce such products at all. After the cancellation of processes for products with low ROI values, the need for part or even the entire loan decreases or eliminates and the financial yield of the enterprise can increase. However, it is necessary to make decisions very carefully, because the mere abolition of some products increases the fixed and total costs of the remaining products, which also applies to CE. Therefore, the ROI values of all remaining products decrease. A correct assessment of the financial implications of these alternatives is only possible through PPROI, because apart from PPROI, there is no information on CE and ROI in the processes for individual products. PPROI is therefore indispensable even in this type of strategic decision-making.

2. FINANCIAL Case Study of the Hat Production Process

The practical application of a definite integral is further illustrated on the process phases in producing a hat. We hope that it will be well imaginable to any reader.



The processes related to the hat from the receipt of the basic material (skins) to the delivery of the hat to the customer are divided into 5 time sections of different lengths, 3 manufacturing and 2 storage. The states of employed capital at the beginning and at the end of i-th section, where i = 1,2,3,4,5, are denoted by the symbols i-1, i.
Manufacturing consists of 3 phases, each of which includes many operations:

1. Separation of fur from leather and processing of fur into hat substance

2. Processing of hat substance into hat body, including dyeing

3. Final shaping and decorating hat

Hat substance and hat body are either the products of the enterprise, i.e., items of sale or are further processed within the enterprise into higher items - hat substance into the hat body, hat body into the hat. Hat substance and hat body are after completion shipped or processed without storage.

The functions $f_{i-1,i}(t)$ characterize the development of capital states within BOM items during the individual phases. In the storage phases, the functions are constant. Linearly increasing functions in the manufacturing phases simplify reality, because capital increases value within processing operations, and between them is constant. However, this cannot be shown in a small graph and the distortion of reality by linear function is minor. The jumps of capital states at the beginning of manufacturing phases display the values of materials (hardeners, dyes, ribbons etc.) purchased JIT for batches of produced items.

Definite integrals $\int_{i-1}^{i} f(t)\mathrm{d}t$ in the first two phases characterize the stocks of capital in the quantities of skins and gradually emerging hat substance needed to produce 1 piece of a hat body and hat. The areas of the adjacent integrals from the process stage involving dyeing are colored with the same color as a hat body and hat for clarity. The sum of definite integrals over all process phases creates a definite integral, characterizing the stocks of capital in the items of the BOM forming the hat and in the hat itself during its storage.

$\int_0^5 f(t)\mathrm{d}t$ = 1,04+1,51+2,80+2,49+3,28 = 11,12 €Year.

Valuation of BOM parts by their prices and costs

States of capital in BOM parts of given product and in product itself can be defined in two ways, related to the concepts consumed capital i.e., costs or created capital i.e., price:

1. The value of the created (and existing) object at a certain moment, which in the case of a finished object is its price and in the case of a work in progress on the object its gradually emerging price. This concept was used in the example on previous page and was easy applicable because the hat substance and the hat body are saleable and as such, they have unambiguous prices. However, if these items were not the subject of sale, it would also be necessary to set their intracompany prices. In general, this would be necessary for all parts of the BOMs for all final products of the enterprise. This would be not only challenging but also problematic from a conceptual point of view.
2. The value of consumed capital contained in the object at a certain moment, ie the stock of capital characterized by the costs incurred for the object in the enterprise up to any relevant moment. The difference from the first concept is evident already in the initial phase of the previous example. While the created capital is constant because the price of skins does not change during their storage, the cost of stored skins increases during the storage phase due to space, handling and other direct and indirect costs related to this phase. At the end of the storage phase, the cost of the skins is higher than the price of the skins. The opposite is true at the end of the second phase, assuming that the price of the hat substance is higher than its cost.

Item	Phase	Process time €	Price €	Direct material €	Initial state of created capital €	Integral state of created capital €Year	Process costs within phase €	Total costs within phase €	Total costs of item €	Initial state of consumed capital €	Integral state of consumed capital €Year	Profit €	Profitability €/ €
Skins	Storage	20	19	19	19	1.04	0.2	19.2	19.2	19	1.05		
Hat substance	Manufacturing	22	27	2	21	1.45	4	6	25.2	21.2	1.40	1.8	0.067
Hat body	Manufacturing	28	40	6	33	2.80	5.5	11.5	36.7	27.2	2.45	3.3	0.083
Hat	Manufacturing	18	57	4	44	2.49	10	14	50.7	40.7	2.25		
Hat	Storage	21	57		57	3.28	0.3	0.3	51	50.7	2.92	6	0.105

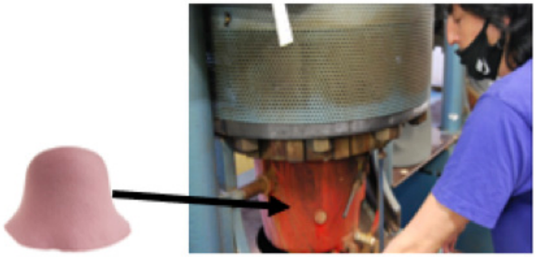
The difference between these two concepts is numerically illustrated by the data in the table.
The first five numeric columns inform on created capital shown in the graph on previous page, in the next five columns are data informing on consumed capital for a certain development of cost of items .

The values of the capital created for the unfinished final product is for information only. In the example, this is the case after completing the hat substance and the hat body in manufacturing the hat. When measuring employed capital in the denominator of ROI, the second concept must be applied and in PPROI it is so. In this case, the amounts of capital continuously or stepwise entering the processes for certain product and the time of their existence in the processes until the moment of product sale are recorded. Yield i.e., profit per product should be expected just from this money-time amount. The gradual increase of profit during the production of the hat does not require any capital inputs, nor can a yield be expected from it, as it is unrealized profit.

Profit, profitability, and possible ROI values

The last column of the table shows the profitability of the hat substance sold, of the hat body sold and the profitability of completed hat. The least profitable is the hat substance, the most profitable finished hat. However, this may not be the case when evaluating production efficiency according to ROI. Capital employed is the lowest in the production of hat substance, the highest in the production of finished hat. In the example, only the current CE is registered, which for hat substance = 1.05 + 1.40 = 2.45, for hat body = 1.05 + 1.40 + 2.45 = 4.90, for finished hat = 1.05 + 1.40 + 2.45 + 2.25 + 2.92 = 10.07. Essential for ROI values are the values of fixed CE, which we have not yet addressed. They will be expressed in a broader context on the following two pages.

Calculation of direct costs and CE in the microphases of processing operations



In the characteristics of the costs generated by the machine on p. 2–5, we emphasized the importance of defining microphases of operations differing in the structure and activity of resources. The example of cost components was related to the manufacturing of product in the metal industry. Microphase application is needed in all industries. We will now explain it in more detail on the processing of the hat.
The image on the left relates to the microphase of exchanging consecutive pieces during the processing of the final part in a hydraulic press, where the basic shape of the hat is created. At this phase, man is active, and the machine is passive. Human generates costs and the machine, in addition to generation costs in the form of depreciation, also represent CE in the process. This also applies to the part of the production hall on which the press is located. The costs arising in the microphase, and its time are reflected in the increase of the current CE in the unfinished hat.

Significantly different financial consequences has the microphase of the automatic pressing of the hat. Here the machine is active, operates independently and generates costs for electricity, steam, compressed air and hydraulic fluid. These costs depend on the physical consumption and price of the items. This microphase also generates maintenance costs and fixed capital associated with internal maintenance. Depreciation, fixed capital contained in the machine and in a part of the building arise in the same way as in the previous microphase. This also applies to the current CE which increases in the unfinished hat. In the third microphase an operator acts independently; after starting the machine he visually inspects the hat, places it in a container or transfers it to the next work center and prepares another piece of hat for placement into the machine. However, the time of these activities can be short compared to the time of automatic pressing, and operator can either provide microphases in follow-up operation or operate more presses working in parallel. At the time of this microphase related to the operation of pressing a certain hat, only labor costs arise, and the CE contained in the unfinished hat grows.

The table shows the main types of costs and CE related to these three kinds of microphases of the operation 60, ie., pressing the hat, which is numbered 26123. The sums over microphases results in individual types of costs and CE for the operation 60 and the sums over individual types of costs and CE determine the total costs and CE for the operation. The values of the current CE are negligible, which is due to the very low values of capital contained in the unfinished hat compared to the fixed CE contained in the press which reflects the time usage of the press. The decisive part of the current CE exists outside the time of processing the product part, at the time when the unfinished or completed parts are in stock.

Part	Operation	Microphase	Time *Minute*	Labor costs €	Machine costs €	Building costs €	Total costs €	Fixed CE *€Minute*	Current CE *€Minute*	Total CE *€Minute*	Total CE *€Year*
28123	60	1	1	0.20	0.0315	0.0062	0.2377	120000	0.1992	80000.2	0.1522
28123	60	2	5		0.3863	0.0310	0.4173	600000	2.0865	600002.09	1.1416
28123	60	3	0.3	0.06			0.06		0.018	0.018	
28123	60	**Total**		0.26	0.4178	0.0372	0.715	720000	2.3037	**72000.31**	**1.2938**

The time of the 2nd microphase, i.e., automatic processing, is determined by the technology department in order to achieve the desired shape and other required properties of the hat. The variable components of machine costs are calculated by the system from the normative consumption of electricity, steam, compressed air and hydraulic fluid and maintenance requirements per hour of activity of the press and the time of microphase in the shaping of the particular hat. The depreciation of machine is calculated in PPROI from the microphase time of the press, its time utilization in the period concerned and from the price of the press and its lifetime. All input data necessary for the calculation of machine costs are known in the enterprise, but it is necessary to record them in PPROI structures. This also applies to space costs. Fixed machine costs and space costs are calculated also in 1st microphase. The record of the times of partial motions and other actions of workers is the basis of the traditional standardization of processes, but for the relevant processing of this data into labor costs it is necessary to assign them to the microphases of the operation. This applies to the 1st and 3rd microphases of the example.

Pricing of hat substance, hat bodies and hats if produced within one enterprise and in the supply chain of enterprises

So far, we have assumed the production of hat substance, hat body and hat within one enterprise. As both the hat substance and the hat body are salable products in the enterprise concerned, their further processing can take place in downstream enterprises of the supply chain. The end customer, the consumer buys only finished hats. The following tables contain the prices of the items calculated by pricing formulas commented on page 2–11. The enterprise producing the hat substance, the hat body and the hat is marked with the letter A, the enterprise buying the hat substance from enterprise A and processing it into the hat body is marked B and the enterprise buying the hat body from enterprise B and processing it into the hat is marked C. The products and processes in enterprise B and C are the same as in enterprise A, we abstract from the logistics processes between enterprises. Under this assumption, the prices of the hat body and the hat in their manufacturing in one enterprise and in the supply chain should be the same. However, this is only the case for pricing according to the new pricing formula in the PPROI.

Product	Enterprise	Direct material €	Process costs €	Total costs €	Price €
Hat substance	A	21	4.2	25.2	28.22
Hat body	A	27	9.7	36.7	41.10
Hat	A	31	20	51	57.12

Product	Enterprise	Direct material €	Process costs €	Total costs €	Price €
Hat substance	A	21	4.2	25.2	28.22
Hat body	B	28.22+6	5.5	39.72	44.49
Hat	C	44.49+4	10.3	58.79	65.84

Product	Enterprise	Direct material €	Process costs €	Total costs €	CE €Year	Price €
Hat substance	A	21	4.2	25.2	15	27
Hat body	A	21+6=27	9.7	36.7	27.5	40
Hat	A	27+4=31	20	51	50	57

Product	Enterprise	Direct material €	Process costs €	Total costs €	CE €Year	Price €
Hat substance	A	21	4.2	25.2	15	27
Hat body	B	27+6=33	5.5	38.5	12.5	40
Hat	C	40+4=44	10.3	54.3	22.5	57

1. Traditional pricing formula: **Product price = Product cost * (1 + (Profit / Cost)** *target*;
   In the example the Profit / Cost target value = 0.12
   In the production of the hat body and the hat in the supply chain, i.e., the hat body in enterprise B, and the hat in enterprise C the calculated prices of products are significantly higher than in production of all products in enterprise A. The reason is duplicate profit calculations in the supply chain. In the production of the hat body in enterprise B, the profit is calculated twice: Once from the costs of the hat substance in enterprise A, the second time from the calculated price hat substance transferred to enterprise B, where this value becomes part of direct material costs. It is just this value = 25.2 (1 + 0.12) * 0.12 = 3.39, that increases the price of the hat body in enterprise B= 44.49 in comparison with price in enterprise A = 41.10. The relative price increase is 8.2%. This senseless increase in prices multiplies in the supply chain of enterprises. The price of the hat produced in enterprise C = 65.84 is therefore 15,27% higher compared to the price of the hat made in enterprise A = 57.12

2. Correct pricing formula: **Product price = Product cost + Product CE * ROI** *target*;
   In the example ROI target = 0.12
   Even in this product pricing, the costs of products in their production in two or more enterprises in the supply chain are higher than in the production of products in one enterprise. The costs of the hat body in enterprise B and the hat in enterprise C are higher than the costs of these products in enterprise A (see the third and fourth tables). But product prices are the same in both alternatives.
   This is because the CE in the production of hat body and hat in enterprise A is significantly higher than in the production of these products in enterprises B and C. The production of hat body in enterprise A also includes the production of hat substance, while in enterprise B it is only the processing of purchased hat substance. The production of a hat in enterprise A includes the production of a hat substance and a hat body, while the production of a hat in enterprise C includes only the processing of a purchased hat body.