

# GENERAL PLANNING OF MINERAL RAW MATERIALS PRODUCTION COSTS AND ECONOMIC EVALUATION OF ORE DEPOSITS

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**Abstract:** *Material production of mineral raw materials is accompanied by specific costs, the general consideration of which is necessary as part of long-term production planning. A special problem that accompanies the definition of these costs is that their planned consideration must be performed much earlier before the start of the production in question. Already in the phase of geological exploration and finding of the ore deposit, a projection of economic profitability must be made, which should enable the relationship between the market price of mineral raw materials and production costs, because the continuation of exploration depends on such a positive result. A special problem arises in the case when due to the low level of exploration there are not enough elements for cost definition of future production. This paper analyzes the application of the method of economic evaluation of deposits, as a complex system of sets of factors and sets of indicators, which allows direct, or in combination with the method of analogy, general view of the costs of future mineral production.*

**Key words:** *costs, planning, economic evaluation, ore deposit.*

## INTRODUCTION

Modern variable and turbulent conditions of production of metallic, non-metallic and energetic mineral raw materials, especially in the part with economic parameters of future production, require special planning seriousness, analyticalness and responsibility. The existing transitional and economic trends in the economics of mineral resources are focused on market-oriented principles and criteria for planning and implementation of the production of mineral resources which are needed for the economy.

(Tošović, 2016a, 2017a, 2019). Companies, as the basic economic entities of the mineral sector, especially in long-term planning of providing mineral resources for mineral production must perform the appropriate planning function, through setting production and business goals, setting strategies for achieving goals and preparing plans, so that organizational work and resource management for production become integrated and successfully achieved (Robbins&Coutler, 2005; Тошовић, 2019).

In the conditions of faster and bigger market changes in the mineral sector, it is necessary for the companies to react adequately in achieving the planned production results and effects. When specific and limited production resources are available, depending on the action of internal and external factors, there may be significant changes in their costs, as a natural expression, and costs, as a financial expression. But there are limits for those, which should not jeopardize the positive economic results and effects of mineral production. In order to achieve successful business and raise the level of competitiveness, in relation to other companies in the mineral sector, it is of special importance to plan and realize a certain level of relevant costs. On the other hand, the market price of mineral raw material is significant, which is subject to oscillations, depending on the acting of local or global factors, especially on the mineral resource exchanges.

Problems of planning the costs of production of mineral raw materials as well as other elements of production are of a specific professional geological-economic type (Тошовић, 2019) and can be solved relatively better through a special analytical-synthetic and economic approach, using geological-economic evaluation as the main framework and economic evaluation as a final

expression with value indicators. Broadly observed, cost planning requires the application of elements of efficient management (Robbins & Coutler, 2005; Tošović, 2010; Tošović & Milovanović, 2008; Mašić & Dželetović, 2015), mineral resource management, then strategic management, the concept of sustainable development (Tošović, 2010), as well as key definitions of characteristics of ore deposits (Тошовић, 2006). In the domestic practice of economic geology, economic criteria and evaluation methods of countries with developed mineral economies (Rudeno, 2012; Rundge, 1998; Torries, 1998; Wellmer, Dalheimer & Wagner, 2010), have enabled a significant improvement in domestic economic evaluation (Tošović, 2011). and modern practices in mineral sector companies. The main goal of this paper is, based on the current level of the subject matter (Tosovic, 2017a, 2017b, 2016, 2014, 2013a, 2013b, 2012) to analytically emphasize the place, role and importance of economic evaluation in successful general cost planning, as a basis for adoption of appropriate business decisions in mineral sector companies.

### **1. Costs of production of mineral products**

Cost planning, as planning element and the basis for budgeting on an annual basis in the companies of the mineral sector is directly dependent on the phase of treatment of mineral raw materials (Tošović, 2008). From the point of view of cost planning and reliability, three characteristic phases can generally be distinguished, namely: (a) the mineral exploration phase; (b) mine construction / production preparation phase; and (c) the mineral production stage. The first phase is accompanied by the highest level of general cost estimation, because there are no necessary safer planning elements in the phase of exploration and definition of the mineral deposit, as an object of future production. The second phase is accompanied by a lower level of general evaluation, because the planning and production elements are approximately known, but certain deviations are possible due to current geological and mining reasons. The third phase with the existence of current production is, in terms of cost planning, the safest, because the basis is the real costs, stated in the existing production.

The key operational and economic problem is the planned determination of cost levels with a sufficient degree of reliability, so that, compared to the market price of mineral raw materials, it does not call into question the positive economic result of operations. After all, such a result is accompanied, from an expert geological point of view, by the definition of commercially viable, ie

balance reserves of mineral resources in the deposit, on the basis of which the following is planned: (a) production capacity; (b) annual production volume; and (c) the quantities of the mineral product on the market. These indicators directly affect the income and expenses of the company, ie the economic result of business.

In the earlier stages, cost level planning is much more complex, responsible and managerially complicated due to the action of a specific time factor. Namely, in the case of larger and geologically and genetically more complex mineral deposits, especially metallic mineral raw materials, geological exploration is longer, more complex, more expensive and economically less certain. In some such deposits, it can take 10-15 or even more years from the beginning of geological exploration and discovery to the beginning of exploitation, ie production and the beginning of income generation. This is a fairly long period in which significant technological, economic and market changes are taking place, and they can significantly affect the evaluation of the economic viability of mineral reserves when it comes to the beginning of exploitation. (Tošović & Milovanović, 2008).

Each of these phases is in some way covered by geological-economic analysis and final economic evaluation, as a separate final chapter, within a separate document, such as: (a) Geological exploration project, which is prepared before the implementation of geological exploration; (b) Report on the results of geological exploration, which is done after the realization of geological exploration; or (c) Study on mineral reserves of the deposit. Within the project, the economic justification of the project cost-effectiveness is analytically prepared and presented, through the planned exploration costs and the expected value of the project results. The report and the study make special economic evaluations of the defined structure. Within this evaluation, as a complex system, in the complete set, there are 9 sets of factors and 3 sets of indicators, which from different aspects include geological and economic analysis of elements important for the initial production planning. Factor sets include the following factors (Тошовић, 2006, 2019): (1) metallogenetic; (2) geological; (3) technical-exploitation; (4) technological; (5) market; (6) regional; (7) socio-political-economic-strategic; (8) geoecological and (9) legislative and legal factors. Indicator sets include the following three groups: (a) natural, (b) value, and (c) synthetic indicators. According to the set goals of scientific-professional and analytical processing, in this paper, Market Factors and Value Indicators are especially important, in the part that includes the

corresponding costs. The subject data from the economic evaluation are directly economically and managerially useful for general cost planning in various phases of deposit exploration and exploitation of mineral resources.

## **2. Cost planning in different phases of mineral resources treatment**

The complexity, reliability and security of planning the costs in question directly depends on the current geological, mining or technological activity in which there is the conquest of mineral resources, ie the preparation of a planned cost projection. Taken as a whole and comprehensively from a cost point of view, particular account should be taken of the specific production stages of the treatment of mineral resources, namely: (a) the geological exploration phase; (b) the exploitation phase; (c) preparation and processing phase; and (d) the market valorisation phase. In the later stages, planning the level of costs is simpler, because it is based on real, ie realized costs, but especially in the initial stages, it is much more complex, responsible and managerially complicated. The practical significance and consequences of this statement are especially pronounced in cases of larger and more complex deposits, where a longer period of time may elapse from the beginning of geological exploration and discovery to the beginning of exploitation, ie production and the beginning of income generation. An illustrative example is the exploration of boron and lithium in the Jadar area in western Serbia, which began in 2004 (Rio Tinto, 2020), the start of exploitation was postponed several times, and according to the current plan will begin in late 2024 and early 2025.

Cost planning in the geological exploration phase is the most complex and is accompanied by the greatest risks according to the evaluation of economic profitability (Tošović, 2018). In addition, this means that there is a need for cost planning at the end of the various stages of geological exploration, namely: (a) regional metallogenetic; (b) prospective; (c) previous ones; and (d) detailed exploration. With the progress of these stages of exploration, more reliable data are obtained, on the basis of which a better economic projection can be given. A positive practical and economic circumstance is that, from the professional point of view, at the end of each of the mentioned stages, a geological-economic evaluation, ie economic evaluation, is done. At the same time, based on the appropriate structure of the analyzed factors, certain indicators are expressed. The key indicators are the costs of

geological exploration and the value of the obtained result, ie the found mineral reserves.

The basic rule in economic geology is that, from the first step of geological exploration, apart from geological exploration aspects, it must be accompanied by an appropriate economic analysis of future profitability, which includes projections of market price of mineral raw materials and comparison with costs of its future production (Тошовић, 2006). The key geological elements and indicators of geological-economic evaluation from the operational aspect are: (a) found mineral reserves and (b) depth of mineral deposit. If the found mineral reserves are small, especially below the minimum reserves, they are insufficient to economically cover investments in mine exploration and construction, ie the costs per 1 t are higher in relation to the market price of 1 t of mineral raw materials. In terms of depth, a particularly important natural indicator is the prohibitive depth, ie the depth to which surface exploitation is possible, and over which one must move to more expensive underground exploitation. The economic dimension of costs in this aspect of analysis is very important, because the costs of surface exploitation are much lower, while the transition to underground exploitation may jeopardize economic viability, especially if the market price of mineral resources is lower, and thus the entire investment venture may be economically unprofitable. In doing so, special attention should be paid to managerial and corporate responsibility for the decision on the implementation of exploration, which will ultimately prove to be an economic unprofitability.

Cost planning in the stage of previous and prospective exploration is indicative at best and is related to cost estimates in the order of magnitude, primarily through the method of analogy with exploration in similar fields, where there was later exploitation of mineral resources. Geological and economic evaluation data are also used for the same, which is done at the end of each stage. The condition for the transition to the next stage and the realization of further investment is a positive evaluation of the results obtained through previous exploration. In case of a negative evaluation, further exploration is suspended, followed by a managerial and financial decision to terminate it. Economically, this situation is undesirable, but there is one positive aspect in economic geology. Namely, it points out that in a certain exploration area it is not necessary to further invest financial resources and spend them unnecessarily, but to invest them in the exploration of some other exploration area.

In the given analysis, a particularly important place is occupied by the projection of costs at the end of previous geological exploration, which ends with an economic evaluation of whether the transition to the next detailed exploration is economically worthwhile, which also means the decision to open a mine. From an economic point of view, the profitability of such work should not later be questioned in any way.

In all these cases, the basic method, which is applied in cost planning, is the method of analogy, ie similarity with some other similar deposit, but combined with the method of geological-economic evaluation (Tošović, 2016b, 2017b). The most favorable variant is if the same company, which is conducting exploration and plans to start exploitation on the found deposit, already has a deposit of the same type and the same type of mineral raw material in the active exploitation process. In this way, the data on the real costs of exploitation can be used directly in the initial analysis, whereby the specifics of the analyzed reservoir in relation to the analogue reservoir must be taken into account. In accordance with the specifics and differences of mineral deposits, which are manifested through indicators, especially values, an appropriate correction must be made, in accordance with the real conditions of the analyzed deposit. Uncritical and non-analytical taking of the amount of costs of analog deposits can lead to major errors and major economic consequences (Tosovic, 2016b, 2017b). In economic evaluation in economic geology, the principle of uniqueness is known, ie the uniqueness of each deposit, which is a separate object, for which, in each individual case, costs and other value indicators must be determined separately. In different deposits, they will have different values, even for the same type of mineral raw material, which in this particular case must be separately analyzed, individually determined and adjusted to the deposit conditions.

The costs should be considered operationally from the point of view of the possibility of application in the planning of total production costs, but also the relation to the market price of mineral raw materials. In this paper, they will be practically analyzed on the basis of a concrete practical example and data of relatively simple sand deposits (Тошовић, 2020a), as mineral raw materials applicable in construction and especially in the Republic of Srpska and the Republic of Serbia in road construction, ie construction of large road corridors. For practical reasons and objective limitations in this paper, the subject of concrete illustration of the way of solving a practical problem, subject economic analysis and elements of economic evaluation will be focused on

highlighting only key value indicators of geological-economic, ie economic evaluation. The subject data from the economic evaluation of the mineral deposit can serve as basic and initial planning values for production planning, which should be considered in accordance with the influence of internal and external factors, in a shorter or longer period of time, and possibly corrected.

In the specific analyzed case of technical and economic evaluation of a smaller sand deposit, which is about to start exploitation (Тошовић, 2020a), the initial calculation of the cost price of 1 m<sup>3</sup> of sand at 262.50 dinars/m<sup>3</sup> (2.2325 EUR/m<sup>3</sup>) was made, which includes the following individual costs: (a) Costs of geological exploration, which amount to 1,392,000 dinars (11,838.78 EUR), which after division with 175,287 m<sup>3</sup> of reserves gives specific costs of 7.94 dinars/m<sup>3</sup> (0.0672 EUR/m<sup>3</sup>); (b) Costs of project documentation in the total amount of RSD 1,900,000 (EUR 16,159.25), ie RSD 10.84 / m<sup>3</sup> (EUR 0.0922 / m<sup>3</sup>); (c) Costs of permits and fees for obtaining conditions of exploration and exploitation, which amount to 132,000 dinars (1,122.64 EUR), or 5.28 dinars/m<sup>3</sup> (0.0449 EUR); (d) Exploitation costs, which include the costs of materials (objects of labor), means of production and wages of workers, so that they amount to 207.30 dinars/m<sup>3</sup> (1.7630 EUR/m<sup>3</sup>). These costs are obtained through a special calculation within the analysis and consideration of Mining evaluation factors, and individually include: Depreciation costs in the amount of 11.10 dinars/m<sup>3</sup> (0.0944 EUR/m<sup>3</sup>). Costs of basic works on sand exploitation, together with normative costs of materials in the amount of 120.64 dinars/m<sup>3</sup> (1.0260 EUR/m<sup>3</sup>). Costs of auxiliary works on fuel delivery, geodetic survey, quality control, etc. in the amount of 9.60 dinars/m<sup>3</sup> (0.0816 EUR/m<sup>3</sup>). Gross salary costs for the planned 2 employees amount to 60.00 dinars/m<sup>3</sup> (0.5103 EUR/m<sup>3</sup>). The costs of mechanization, ie hydraulic excavator and truck on a daily, monthly and annual level are analyzed separately. On the other hand, the analysis and presentation of consumption norms for diesel fuel, lubricants, oil and truck tires is performed individually. (e) Maintenance costs were analyzed at the level of 5% of the purchase value of the equipment, ie 5.50 dinars/m<sup>3</sup> (0.0468 EUR/m<sup>3</sup>). (f) Insurance costs were analyzed at the level of 1% of the purchase value of the equipment, ie 1.10 dinars/m<sup>3</sup> (0.0093 EUR/m<sup>3</sup>). (g) The costs of the fee for the use of mineral resources are analyzed at the level of 5% of the total income, ie 560,000 dinars per year (4,762.73 EUR), which with an annual exploitation of 25,000 m<sup>3</sup> means 22.40 dinars/m<sup>3</sup> (0.1905 EUR/m<sup>3</sup>). (h) The costs of

preserving and improving the environment, together with the costs of reclamation, have been empirically calculated at about 3% of the costs of basic exploitation works, which amounts to 3.60 dinars/m<sup>3</sup> (0.0306 EUR/m<sup>3</sup>). (i) Other unforeseen costs were analyzed at the level of 2% of total costs, ie 5.15 dinars/m<sup>3</sup> (0.0438 EUR/m<sup>3</sup>).

The initially defined market price of sand is 320 dinars/m<sup>3</sup> (2.7215 EUR/m<sup>3</sup>), which, after VAT and profit tax, means the final market price of 429.45 dinars/m<sup>3</sup> (3.6524 EUR/m<sup>3</sup>). The subject relations indicate a profitability of 15.50%. Thus, the net value of the reserve unit is 57.50 dinars/m<sup>3</sup> (0.4890 EUR/m<sup>3</sup>). The total value of sand reserves of the subject deposit with reserves of 175,287 m<sup>3</sup>, sufficient for the planned exploitation in a period of 7 years, is 10,079,002 dinars (85,720.59 EUR).

All these values are determined during the geological and economic evaluation of the deposit, in accordance with the planned production conditions, the specifics of the quality of the mineral raw material, cost projections and the market price of sand, as the final product. Without a specific technical and economic analysis, appropriate to the characteristics of the subject sand deposit, it is not possible to properly plan the value indicators, especially costs and their relationship with the market price. A very illustrative example is the second sand deposit (Тошовић, 2020a), when the production costs are 479.33 dinars/m<sup>3</sup> (4.0776 EUR/m<sup>3</sup>), and on the other hand the average selling price is 550.00 dinars/m<sup>3</sup> (4.6777 EUR/m<sup>3</sup>), ie the net value of the reserve unit of 70.67 dinars/m<sup>3</sup> (0.6010 EUR/m<sup>3</sup>). Non-analytical and uncritical use of the method of analogy with the application of the stated production costs to the first deposit, would mean economically unprofitable production of sand, ie non-commercial character or off-balance sheet of the subject mineral reserves of sand. Hence, the method of geological-economic, ie economic evaluation of the subject deposit, for application in the process of planning production costs, ie budgeting for the needs of business planning and business decision-making, proves to be much safer and more reliable.

Planning the costs of production of mineral raw materials in the case of an active deposit, on which exploitation takes place, is safer and simpler. Then the actual realized costs are used for the initial analysis and planning. However, even in that case, it is necessary to use data related to geological and economic evaluation. This especially refers to the change in the quality of mineral raw materials in the parts of the deposit planned for exploitation. Particularly symptomatic is the case of lowering the content of the useful component in the part of

the deposit (eg lead and zinc content from 6% to the limit content of 3%), which is why it is necessary to excavate a larger amount of poorer straight ore to meet the plan. produce. In that case, the costs of transport were also increased, as well as the preparation and processing until the final product was obtained for the market. Applying the method of analogy in such situations will not enable more successful planning, it can even lead to major economic mistakes. Planning must be based on the analytical application of the method of geological-economic evaluation and appropriate natural and value indicators within the evaluation, combined with the data obtained by the method of analogy.

In certain periods with the appearance of economic and other types of crises, there is an unplanned increase in costs, but also a change in the market price of mineral raw materials. As a particularly interesting and current example of the latest developments in the mineral sector, the impact of the current change in mineral prices in the current market, production and economic problems caused by the COVID19 pandemic can be cited. For example. The price of copper on the stock exchange (Тошовић, 2020b) is from 5,737 USD/t from February 14, 2020 reduced to 4,855 USD/t from 20.03.2020 and then to 4,617 USD/t from 23.03.2020 which means a drop of 20%. Even more illustrative is the change in the price of oil (Тошковић, 2020c), e.g. type Urals, whose price is from 53.05 USD/bbl from 14.02.2020. year, reduced to 19.90 USD/bbl from 19.03.2020 and then at 16.40 USD/bbl from 21.04.2020 which means a drop of 70%. The price of WTI oil, which is 20.04.2020, stands out as particularly illustrative and price-symptomatic. was -37.63 USD/bbl. Extremely unusual production and economic situation in which oil companies, instead of income and profit from sold oil, are forced to pay additional unplanned costs, to pay customers to take it over, due to the problem of accommodation for the produced quantities of oil. For a complete economic analysis, one should keep in mind the feedback effect that the price of mineral raw material has on the volume of production, the economic effects of production and the business effects of the companies in the mineral sector. In doing so, special account should be taken of the length of the period in which the price of the mineral in question may jeopardize the balance of reserves, and thereby affect the productivity of mineral sector enterprises. Of particular influence are the announcements of a significant economic crisis, which will especially follow the end of the COVID19 pandemic. This will have a further effect on the increase in production costs, as well as the required volume of production of mineral

raw materials, given the announced significant reduction in the production of many industries that consume them. This calls into question the degree of profitability of work, as well as the need to invest special funds in the exploration of new mineral reserves, without prior consideration of the currently available production capacity and production quantities by individual mineral species. All these changes require special geological and economic monitoring, through which the key factors and indicators of geological and economic evaluation will be analyzed and corrected, in accordance with the crisis effects. As such, they are a good starting point for cost corrections, as well as a planned view and prediction of business success in a shorter and longer period of time.

Practical aspects of the elements of economic evaluation of deposits show direct applicability in cost planning in companies in the mineral sector. Managers and persons who plan costs and make decisions, should take into account the value indicators of economic evaluation of the mineral deposit, in order to better and more reliably define the initial, planned, anticipated, standardized or expected costs as planning elements in business. From the managerial, personnel and organizational point of view, it is the best practice to include an economic geologist in the preparation and planning of costs, as an expression of the elements of production, who is competent for academic geological-economic evaluation. In that way, the best planning bases for cost planning, production planning, profitability planning, important for the economic success of the company and successful work and functioning of the mineral economy and mineral sector of Republika Srpska and the Republic of Serbia in the upcoming economic and development period can be obtained.

## CONCLUSION

Modern variable and turbulent conditions of mineral production, especially in the part with economic parameters of future production, require special planning seriousness, analyticalness and responsibility. Cost planning, as planning element and basis for budgeting in mineral sector companies, directly depends on the treatment phase of the mineral resource. The key economic problem is the planned determination of cost levels with a sufficient degree of reliability that in relation to the price of mineral raw materials, it does not jeopardize the positive economic result of business. The complexity, reliability and security of planning the costs directly depend on the current geological, mining or technological activity in the

development of metallic, non-metallic and energy minerals. Cost planning in the geological exploration phase is the most complex and is accompanied by the greatest risks in terms of assessing economic viability, especially in the initial stages of exploration. The positive economic circumstance is that, at the end of each stage of the exploration, a geological-economic evaluation is made, ie an economic evaluation. Among the key indicators of the evaluation are the costs of geological exploration and the value of the found mineral reserves. Data from the economic evaluation of the mineral deposit can serve as a starting point for cost planning of production, which should be considered in accordance with the influence of internal and external factors, in a shorter or longer period of time. Planning must be based on the analytical application of the method of geological-economic evaluation and appropriate natural and value indicators within the evaluation, combined with the data obtained by the method of analogy.

In certain crisis periods, there is an unplanned increase in costs, but also a change in the market price of mineral raw materials. Such changes require constant geological and economic monitoring, through which the key factors and indicators of geological and economic evaluation will be monitored, analyzed and corrected, in accordance with the crisis effects. As such, they are a good starting point for cost corrections, as well as for planned forecasting in a shorter and longer period of time. Practical aspects of the elements of economic evaluation of deposits show direct applicability in cost planning in companies in the mineral sector. In that way, the best planning bases for cost planning, production planning, profitability planning, important for the economic success of individual companies and successful work and functioning of the mineral economy and mineral sector of Republika Srpska and the Republic of Serbia in the upcoming economic and development period can be obtained.

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## SUMMARY

In the conditions of faster and bigger market changes in the mineral sector, it is necessary for the companies to react adequately in achieving the planned production results and effects. In order to

achieve successful business and raise the level of competitiveness in relation to other companies in the mineral sector, it is of special importance to plan and realize a certain level of the subject costs of mineral production.

Cost planning, as planning element and basis for budgeting on an annual basis in the enterprises of the mineral sector, is directly dependent on the phase of mineral raw material treatment, among which are: (a) the mineral exploration phase; (b) mine construction / production preparation phase; and (c) the mineral production phase.

In the earlier phases, the planning of cost levels is managerially more complicated due to the action of a specific time factor in the period from the discovery to the beginning of the exploitation of the mineral raw material. Cost planning in the geological exploration phase is the most complex and is accompanied by the greatest risks according to the evaluation of economic profitability. As the exploration stage progresses, more reliable data are obtained, on the basis of which a better economic projection of costs can be given. A positive economic circumstance is that, at the end of each of the above stages, a geological-economic evaluation is made, ie an economic evaluation, with value indicators, on the basis of which appropriate costs can generally be successfully planned.

The costs should be considered operationally from the point of view of the possibility of application in the planning of the total production costs, but also in the relation to the market price of the mineral raw material. According to the specifics and differences of mineral deposits, which are manifested through indicators, especially values, an appropriate correction must be made, in accordance with the real conditions of the analyzed deposit. Uncritical and non-analytical taking of the amount of costs of analog deposits can lead to major errors and major economic consequences.

In practice, the method of geological-economic, ie economic evaluation of the subject deposit, for application in the process of planning production costs, ie budgeting for the needs of business planning and business decision-making, has proven to be more reliable. Planning must be based on the analytical application of the method of geological-economic evaluation and appropriate natural and value indicators within the evaluation, combined with the data obtained by the method of analogy.

Crisis changes in the conditions of mineral production require special geological and economic monitoring, through which the key factors and indicators of geological and economic evaluation will be analyzed and corrected, in accordance with the crisis effects. As such, they are a good starting point for cost adjustments, as well as a planned forecast of business success in a shorter and longer period of time.