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Model for Assesing the Cost of Accidents and Diseases in the Workplace

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***Abstract*— Worldwide, various types of cost assessment methodology exist in case of accident at work. Costs that may arise in the event of an accident at work can be of a great burden to the budget of a project in every given industry leading to unforeseen financial losses, loss of time and important human resourced, and therefore it may result with ending the working project. For that purpose in 2007, Republic of Macedonia like the rest of the EU countries implements the European Directives of safety and health at work. That means that all organizations must follow the given standards and regulations of safety and health at work such as: applying appropriate employee training, conducting regular medical examinations to the employees, preparing a risk assessment study of the workplace, monitor and test the equipment and the machines that are used in the everyday process of work.**

Keywords— risk assessment methodology; safety, health, costs benefit

I. INTRODUCTION

International Labor Organization, in a study regarding health and safety at work in the US, 2003, says that death and disease arising from the cost of workplace have much exposure to more risks in society. There is no way to know what role have these studies played in the social consensus that led to the formation around proactive protection policies at work in most industrialized countries, but their importance in the public domain and the resources continually allocated to update and improve them both indicate that they have the power to motivate.

Harberger and Jenkis (2002) define cost-benefit analysis as a sum of tools for directing decisions on whether to take certain course of action or not. Pearce (1988); Snell (1997); Preez (2004) define cost-benefit analysis as methodology for estimate of the costs and benefits enabling development of numerous comparisons and forecast of benefits and costs that should be considered or measured in order to sum them. There are great number of different definitions and views about cost-benefit analysis.

The original theoretical basis for the cost – benefit analysis, as a technique for economic assessment of public investments was laid in 1930 when US engineering corps created methodology for justification of Congress' projects (Lagas, 1999). First system usage of cost – benefit analysis happened in USA in relation to investment programs for water resources in Northern America in 1930s. It was noted that the mass public expenditure undertaken for the development of selected river valleys and public benefits of such schemes are considered unreliable. Since the 1930s, cost - benefit analysis is a popular tool for evaluating public sector projects and is one of the oldest techniques that have been developed in the US to assess the implications of alternative schemes on water resources, by which its application has spread rapidly on various activities in the public sector in all parts of the world.

The same process can be seen on national level. Every industrialized country has national legislation and adheres to international conventions that force protection of health and safety of own workforce, though advocates of safety at work have found it useful to demonstrate the economic costs of the decline in work. "Safety in numbers", one of the highest profile publications of the International Labor Organization (ILO) in the field of safety at work, suggests that 4 percent of global income is lost due to occupational injuries and diseases, discovery quoted around the world numerous times.

II. MATERIAL AND MODEL

A. Decision - parameters for analysis of investments - methods used for cost - benefit analysis

There are three criteria used in the process of decision – making. They are:

1. NPV - Net Present Value

The difference between the present value of cash inflows and the present value of cash outflows. NPV (Net Present Value) is used to analyze the profitability of the investment or project.

$$NPV = C_0 + \sum_{t=1}^{N} \frac{C_t}{(1+r)^t} \quad or, in\ short\ \ NPV = \sum_{t=0}^{N} \frac{C_t}{(1+r)^t} \tag{1}$$

where:

- C_t = net cash inflow during the period,
- C_0 = initial investment,
- r = discount rate (the rate of return that can be earned by investment in the financial markets with similar risk, the opportunity cost of capital),
- t = number of time periods.

2. IRR - Internal rate of return

Internal rate of return (IRR) or economic rate of return is the rate used to measure and compare the profitability of investments.

$NPV_{(r)} = 0$ - discount rate makes the current net value of all cash flows of a project to be equal to zero.

In the method of internal rate of return (IRR), the criterion for acceptance of the project is that the IRR must exceed the social discount rate. Given both independent projects and budget limitations, you should choose one with a higher internal rate of return before one with a lower rate. The internal rate of return is the discount rate that is created by the whole system - the benefits and costs – equals zero:

$$IRR = \sum_{t-0}^{n} \frac{B}{(1+r)^t} t = 0 \quad (2)$$

The internal rate of return is another method for determining the value that does not depend on the determination of the discount rate and expresses the value in terms of percentage. The internal rate of return is based on the assumption that the flows of costs are reinvested in the internal rate of return.

Therefore, the internal rate of return cannot be used to calculate the costs and benefits, because the internal rate of return can give results that are inconsistent with the ranking based on the method of net present value.

3. BCR – Benefit Cost Ratio

Benefit cost ratio is defined as ration between the present value of benefits and present value costs:

$$BCR = \frac{\sum_{t=0}^{n} \frac{B_t}{(1+i)^t}}{\sum_{t=0}^{n} \frac{C_t}{(1+i)^t}} = B/C \quad (3)$$

Criteria for acceptance of the project is that the reduced rate of cost benefits shall not exceed one. The choice between each excluded projects, for best acceptance it will be to choose a project with the highest rate of cost benefits. However, a typical problem with the discount rate is getting accurate cash flow.

4. WTP - Willingness to pay

Another method is the willingness to pay. Willingness to pay for improvement in health is in a function of improving productivity and is expressed as:

$$WTP = PP + CS \quad (4)$$

where: PP = the amount paid
CS = consumer surplus

Willingness to pay reflects the amount that someone who has no product will be ready to pay for it. It represents the maximum amount of money that people are willing to pay in exchange for the improvement of circumstances or consumer surplus brought about by the policy of using.

B. *Cost-benefit analysis with software*

Below, the software by which we can calculate the benefit of appropriate preventive measures in occupational safety expressed by economic indicators-money is shown. For this purpose, an EXCEL program is developed, by which help we can demonstrate the model of Cost-Benefit Analysis.

III. RESULTS AND ANALYSIS

Theoretical design of the cost - benefit analysis by different types of benefits, security research and direct / indirect costs of accidents is implemented into the software. Different types of costs incurred from accidents caused by the fault of the employer in a particular industry as a consequence of avoiding adherence to the measures and principles set by management for Safety and Health at Work are also presented. These costs might be key in economic endurance of the project itself. Based on that, the costs from this character are distributed in two groups: costs incurred to improve the safety of workers and reducing the risk of accident and costs incurred as a result of injury to a worker due to violation of standards of safety and health at work.

Due to the need for unification of the respective benefits and costs in Cost-Benefit analysis in program Cost-Benefit-Analysis.xls, costs are defined as:

Costs 1, Costs 2, ... Costs 5, while benefits as Benefit 1, Benefit 2,... Benefit 5. They can be, for example, costs caused by production cuts due to worker injury or disease at work, medical expenses, legal fees etc., while the benefits can be to reduce accidents, reduce medical cases, increase productivity, reduced sick leaves etc. Input parameters for analysis are given in next Table:

Table 1: Input parameters

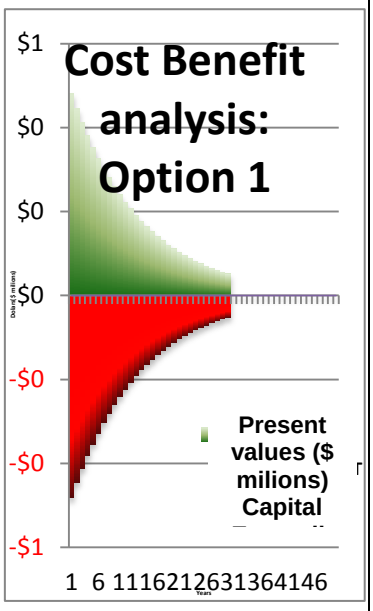
	Option 1 < example 1 >	Option 2 < example 2 >	Option 3 < example 3 >	Option 4 < example 4 >
Estimation period (years)	30	30	30	30
Capital expenditures	$0	$2.000.000	$30.000.000	$55.000.000
Whole life costs	$15.000.000	$17.000.000	$45.000.000	$70.000.000
Cost -Benefit analyses				
Present Value of profit	$5.849.716	$7.604.631	$39.841.423	$47.718.390
Capital Expenditures	$5.849.716	$7.849.716	$35.479.345	$43.903.348
Benefit-	1,00	0,97	1,12	1,09

cost ratio				
Net Present Value	$0	$245.085	$4.362.077	$3.815.042
Multi-criteria analysis of non-material expenses				
Criteria 1	1,50	2,50	2,50	2,50
Criteria 2	1,25	2,25		1,50
Criteria 3	0,60	0,90	1,20	1,20
Criteria 4	0,40	0,30	0,50	0,80
Weighted rating	3,8	6,0	4,2	6,0

In the model itself, four different examples are presented and at the end, multi-criteria analysis of non-material costs and fees, if any, are shown, where four different criteria are defined.

Table 2: Example 1

Cost Benefit Analysis	**Investment proposal**			
Option 1:	**Example 1**			
Key assumptions				
Discount rate (%)	8,00%			
Periodic assessment (years)	30 years			
Summary results of the analysis				
Capital expenses per 10 years	$0			
Whole life costs	$15.000.000			
Present Value of benefits	$5.849.716			
Present value of costs	$5.849.716			
Benefit-cost ratio	1,00			
Net present value	$0			
Years	**2015**	**2025**	**2035**	**2045**

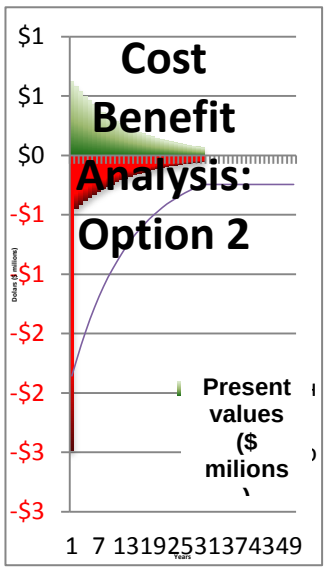


Discounted factor (half-year)	0,96225	0.44571	0.20645	0.10328
Discounted factor (at beginning of year)	1,00000	0.46319	0.21455	0.10733
Benefit 1	$100.000	$100.000	$100.000	$100.000
Benefit 2	$100.000	$100.000	$100.000	$100.000
Benefit 3	$100.000	$100.000	$100.000	$100.000
Benefit 4	$100.000	$100.000	$100.000	$100.000
Benefit 5	$100.000	$100.000	$100.000	$100.000
Total Benefits (half-year)	$500.000	$500.000	$500.000	$500.000
Present Value of benefits (half-year)	$481.125	$222.854	$103.225	$51.638
Present Value of benefits	$5.849.716			
Costs 1	-$100.000	-$100.000	-$100.000	-$100.000
Costs 2	-$100.000	-$100.000	-$100.000	-$100.000
Costs 3	-$100.000	-$100.000	-$100.000	-$100.000
Costs 4	-$100.000	-$100.000	-$100.000	-$100.000
Costs 5	-$100.000	-$100.000	-$100.000	-$100.000
Total Costs (half-year)	-$500.000	-$500.000	-$500.000	-$500.000
Capital costs (at beginning of year)	$0	$0	$0	$0
Total costs	-$500.000	-$500.000	-$500.000	-$500.000
Total capital costs	$0			
Overall cost of living	-$15.000.000			
Present	-	-$222.854	-	-

value of costs (half-year)	$481.125		$103.225	$51.638
Present value of costs (at beginning of year)	$0	$0	$0	$0
Present value of costs (at current year)	-$481.125	-$222.854	-$103.225	-$51.638
Present value of costs	-$5.849.716			
Net cash flow	$0	$0	$0	$0
Net present value (at current year)	$0	$0	$0	$0
Cumulative NPV	$0	$0	$0	$0
Data to draw the graph:				
Year	0	10	20	30
Present Value of benefits ($ milions)	$ 0.481	$ 0.223	$ 0.103	$ 0.052
Present value of costs ($ milions)	- $ 0.481	- $ 0.223	- $ 0.103	- $ 0.52
Cumulative net present value ($ milions)	$ -	$ -	$ -	$ -

Table 3: Example 2

Cost Benefit Analysis	**Investment proposal**	
Option 2:	**Exampl 2**	
Key assumptions		
Discount rate (%)	8,00%	
Periodic assessment (years)	30 years	
Summary results of the analysis	**In million $**	
Capital expenses per 10 years	$2.000.	
Whole life costs	$17.000	
Present Value of benefits	$7.604.	
Present value of costs	$7.849.	
Benefit-cost ratio	0.97	
Net present value	-$245.	

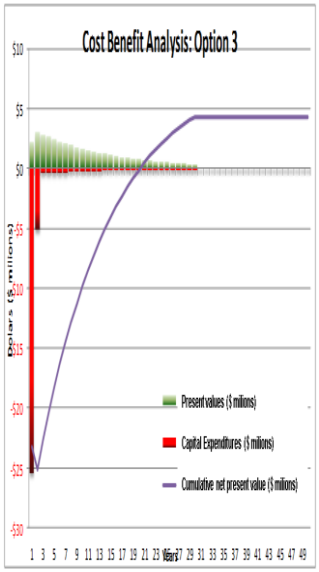


Years	2015	2025	2035	2045
Discounted factor (half-year)	0,96225	0.44571	0.20645	0.10328
Discounted factor (at beginning of year)	1,00000	0.46319	0.21455	0.10733
Benefit 1	$250.000	$250.000	$250.000	$250.000
Benefit 2	$100.000	$100.000	$100.000	$100.000
Benefit 3	$100.000	$100.000	$100.000	$100.000
Benefit 4	$100.000	$100.000	$100.000	$100.000
Benefit 5	$100.000	$100.000	$100.000	$100.000
Total Benefits (half-year)	$650.000	$650.000	$650.000	$650.000
Present Value of benefits (half-year)	$625.463	$289.710	$134.192	$67.129
Present Value of benefits	$7.604.631			
Costs 1	-$100.000	-$100.000	-$100.000	-$100.000
Costs 2	-$100.000	-$100.000	-$100.000	-$100.000
Costs 3	-$100.00	-$100.0	-$100.0	-$100.

	0	00	00	000
Costs 4	-$100.000	-$100.000	-$100.000	-$100.000
Costs 5	-$100.000	-$100.000	-$100.000	-$100.000
Total Costs (half-year)	-$500.000	-$500.000	-$500.000	-$500.000
Capital costs (at beginning of year)	-$2.000.000	$0	$0	$0
Total costs	-$2.500.000	-$500.000	-$500.000	-$500.000
Total capital costs	-$2.000.000			
Overall cost of living	-$17.000.000			
Present value of costs (half-year)	-$481.125	-$222.854	-$103.225	-$51.638
Present value of costs (at beginning of year)	-$2.000.000	$0	$0	$0
Present value of costs (at current year)	-$2.481.125	-$222.854	-$103.225	-$51.638
Present value of costs	-$7.849.716			
Net cash flow	-$1.850.000	$150.000	$150.000	$150.000
Net present value (at current year)	-$1.855.662	$66.856	$30.967	$15.491
Cumulative NPV	-$1.855.662	-$887.146	-$438.535	-$245.085
Data to draw the graph:				
Year	0	10	20	30
Present Value of benefits ($ millions)	$ 0.625	$ 0.290	$ 0.134	$ 0.067
Present value of costs ($ millions)	- $ 2.481	- $ 0.223	- $ 0.103	- $ 0.052
Cumulative net present value ($ millions)	- $ 1.856	- $ 0.887	- $ 0.439	- $ 0.245

Table4: Example 3

Cost Benefit Analysis	**Investment proposal**			
Option 3:	**Example 3**			
Key assumptions				
Discount rate (%)	8,00%			
Periodic assessment (years)	30 years			
Summary results of the analysis				
Capital expenses per 10 years	$30.000.000			
Whole life costs	$45.000.000			
Present Value of benefits	$39.841.423			
Present value of costs	$35.479.345			
Benefit-cost ratio	1.12			
Net present value	$4.362.077			
Years	**2015**	**2025**	**2035**	**2045**
Discounted factor (half-year)	0,96225	0.44571	0.20645	0.10328
Discounted factor (at	1,00000	0.46319	0.21455	0.10733



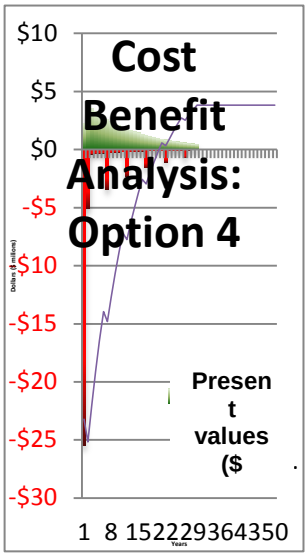
beginning of year)				
Benefit 1	$400.000	$800.000	$800.000	$800.000
Benefit 2	$1.000.000	$1.000.000	$1.000.000	$1.000.000
Benefit 3	$100.000	$100.000	$100.000	$100.000
Benefit 4	$100.000	$100.000	$100.000	$100.000
Benefit 5	$750.000	$1.150.000	$1.500.000	$1.500.000
Total Benefits (half-year)	$2.350.000	$3.500.000	$3.500.000	$3.500.000
Present Value of benefits (hals-year)	$2.261.289	$1.559.978	$722.572	$361.466
Present Value of benefits	$39.841.423			
Costs 1	-$100.000	-$100.000	-$100.000	-$100.000
Costs 2	-$100.000	-$100.000	-$100.000	-$100.000
Costs 3	-$100.000	-$100.000	-$100.000	-$100.000
Costs 4	-$100.000	-$100.000	-$100.000	-$100.000
Costs 5	-$100.000	-$100.000	-$100.000	-$100.000
Total Costs (half-year)	-$500.000	-$500.000	-$500.000	-$500.000
Capital costs (at beginning of year)	-$25.000.000	$0	$0	$0
Total costs	-$25.500.000	-$500.000	-$500.000	-$500.000
Total capital costs	-$30.000.000			
Overall cost of living	-$45.000.000			

Present value of costs (half-year)	-$481.125	-$222.854	-$103.225	-$51.638
Present value of costs (at beginning of year)	-$25.000.000	$0	$0	$0
Present value of costs (at current year)	-$25.481.125	-$222.854	-$103.225	-$51.638
Present value of costs	-$35.479.345			
Net cash flow	-$23.150.000	$3.000.000	$3.000.000	$3.000.000
Net present value (at current year)	-$23.219.837	$1.337.124	$619.347	$309.828
Cumulative NPV	-$23.219.837	-$8.479.130	-$493.084	$4.362.077
Data to draw the graph:				
Year	0	10	20	30
Present Value of benefits ($ milions)	$ 2.261	$ 1.560	$ 0.723	$ 0.361
Present value of costs ($ milions)	- $ 25.481	- $ 0.223	- $ 0.103	- $ 0.052
Cumulative net present value ($ milions)	- $ 23.220	- $ 8.479	- $ 0.439	$ 4.362

Table5 : Example 4

Cost Benefit Analysis	**Investment proposal**	
Option 4:	**Example 4**	
Key assumpti		

ons	
Discount rate (%)	8,00%
Periodic assessment (years)	30 years
Summary results of the analysis	
Capital expenses per 10 years	$55.000.000
Whole life costs	$70.000.000
Present Value of benefits	$47.718.390
Present value of costs	$43.903.348
Benefit-cost ratio	1.09
Net present value	$3.815.042



Years	2015	2025	2035	2045
Discounted factor (half-year)	0,96225	0.44571	0.20645	0.10328
Discounted factor (at beginning of year)	1,00000	0.46319	0.21455	0.10733
Benefit 1	$400.000	$1.200.000	$1.200.000	$1.200.000
Benefit 2	$1.000.000	$1.000.000	$1.000.000	$1.000.000
Benefit 3	$100.000	$500.000	$500.000	$500.000
Benefit 4	$100.000	$100.000	$100.000	$100.000
Benefit 5	$750.000	$1.150.000	$1.500.000	$1.500.000
Total Benefits (half-year)	$2.350.000	$4.300.000	$4.300.000	$4.300.000
Present Value of benefits (hals-year)	$2.261.289	$1.916.545	$887.731	$444.087
Present Value of benefits	390			
Costs 1	-$100.000	-$100.000	-$100.000	-$100.000
Costs 2	-$100.000	-$100.000	-$100.000	-$100.000
Costs 3	-$100.000	-$100.000	-$100.000	-$100.000
Costs 4	-$100.000	-$100.000	-$100.000	-$100.000
Costs 5	-$100.000	-$100.000	-$100.000	-$100.000
Total Costs (half-year)	-$500.000	-$500.000	-$500.000	-$500.000
Capital costs (at beginning of year)	-$25.000.000	$0	$0	$0
Total costs	-$25.500.000	-$500.000	-$500.000	-$500.000
Total capital costs	-$55.000.000			
Overall cost of living	-$70.000.000			
Present value of costs (half-year)	-$481.125	-$222.854	-$103.225	-$51.638
Present value of costs (at beginning of year)	-$25.000.000	$0	$0	$0
Present value of costs (at current year)	-$25.481.125	-$222.854	-$103.225	-$51.638
Present value of costs	-$43.903.348			
Net cash flow	-$23.150.000	$3.800.000	$3.800.000	$3.800.000
Net present value (at	-$23.219.837	$1.693.691	$784.507	$392.449

current year)				
Cumulative NPV	- $23.219.837	- $7.177.333	- $583.604	$ 3.815.042
Data to draw the graph:				
Year	0	10	20	30
Present Value of benefits ($ milions)	$ 2.261	$ 1.917	$ 0.888	$ 0.444
Present value of costs ($ milions)	- $ 25.481	- $ 0.223	- $ 0.103	- $ 0.052
Cumulative net present value ($ milions)	- $ 23.220	- $ 7.177	$ 0.584	$ 3.815

IV. Conclusions

One of the more difficult things for every industry is planning the amount of expenses that will be spent in the sector of health and safety of workers during execution of their assigned tasks over certain period of time. Cost- benefit analysis is one kind of methodology to assess the costs and benefits that helps to make numerous comparisons and predictions of benefits and costs that should be taken into account.

Methodology for estimation of costs for one company in a cases of accident or professional disease at work, type of costs, how to achieve cost reduction and how to anticipate these costs, is developed and presented in this article. For this purpose, a program that measures costs and makes analysis of the profitability for investing in the safety and health at work, is developed.

Through examples of studies by other authors, we have seen other similar methodologies for calculating costs in a case of accidents or occupational diseases and methods for analyzing the parameters involved in building these methodologies and cost-benefit analysis to examine the effect of preventing the creation of pre - conditions to reduce the risk of accident or occupational disease at work.

However, no matter how much we strive to improve the conditions related to safety and health at work, well implemented system for safety and health at work and yet continue to have accidents and injuries at work, which in turn lead to a increased costs associated with safety and health of the employees. The methodology developed in this article can be applied in many industries and is expected to lead to significant material savings to companies in respect of payment of damages to employees, damages by occupational diseases, attorney fees and court costs, etc. Action plan for implementation of the planned activities will be relieved from time interruptions due to accidents and diseases, will bring savings in terms of loss of material damage due to delays in the deadlines for implementation, etc.

References

[1] Oxenburgh, M. & Marlow, P. (1996) The Productivity Assessment Tool: Computer Based Cost Benefit Analysis Model for the Economic Assessment of Occupational Health and Safety Interventions in the Workplace. Journal of Research-ECON Proceeding

[2] Elias Okede Ikpe MSc, DEVELOPMENT OF COST BENEFIT ANALYSIS MODEL OF ACCIDENT PREVENTION ON CONSTRUCTION PROJECTS , PhD dissertation, Wolverhampton University, Great Britain, 2011

[3] Beatson, M. and M. Coleman., International Comparisons of the Economic Costs of Work Accidents and Work-Related Ill-Health, in J. Mossink and F. Licher (eds.) Costs and Benefits of Occupational Safety and Health: Proceedings of the European Conference on Costs and Benefits of Occupational Safety and Health 1997

[4] Marjolein de Weerd (TNO); Rory Tierney (Matrix); Birgit van Duuren-Stuurman (TNO); Evelina Bertranou (Matrix), *Estimating the cost of accidents and ill-health at work: A review of methodologies*, European Risk Observatory, 2014

[5] Snell, M. (1997) Cost-Benefit Analysis for Engineers and Planners. Thomas Telford Ltd UK