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*intelligent decision support system,
project cash flow management*

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MANUFACTURING PROJECTS CASH-FLOW DYNAMICS AND RISK MANAGEMENT

A project portfolio is referred to as an optimal combination of specified projects to best achieve defined goals of an enterprise. The goals may imply either economic and business strategies, or technical strategies. This paper presents an idea of project portfolio management in intelligent decision support systems (IDSS), which emphasizes on the problem of resource allocation, in particular cash. A rational way of distributing cash among different projects is modeled. We propose a concept of *cash-flow dynamics module*, which can be plugged into IDSS. The IDSS allows project managers to make decisions regarding the order of priority for projects' launching times based on risk and profitability of projects. This paper describes how this module can support cash-flow management processes, from budgeting for future periods to tracking real-time cash flow. Based on an analogy between cash-flow processes and physical flow of fluid, a cash-flow dynamics model is introduced. The theory of Bernoulli principle for cash-flow planning and tracking is applied.

1. INTRODUCTION

In a collaborative enterprises network for conglomerate companies, typically there are one head office (management) company, several production companies, and different market companies. Every company works in its own enterprise resource planning (ERP) system with certain functionalities. The data flow in the collaborative network is organized through ERP systems**.** The consistency of data is important and ensured by data replication between the head office ERP system and ERP systems of market and production companies, as seen in Fig. 1. It includes modules for finance management, warehouse management, marketing management, sales and purchase management. The replicated data for market companies include customer data, product data, sales orders, purchase orders, and daily sales reports. The replicated data for production companies include sales orders and purchase orders. For

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analytical purposes the data is transmitted daily to central data warehouse, which enables the head office to receive required management reports automatically.

Although data can be shared extensively among ERP systems, they still do not directly support decision makings. Thus, intelligent decision support systems (IDSS) integrated with ERP systems are useful for decision makers to perform the analysis of the projects and include them into enterprise project portfolio. In our previous research of (IDSS) for manufacturing projects, a model of project management portfoliowas proposed [4].

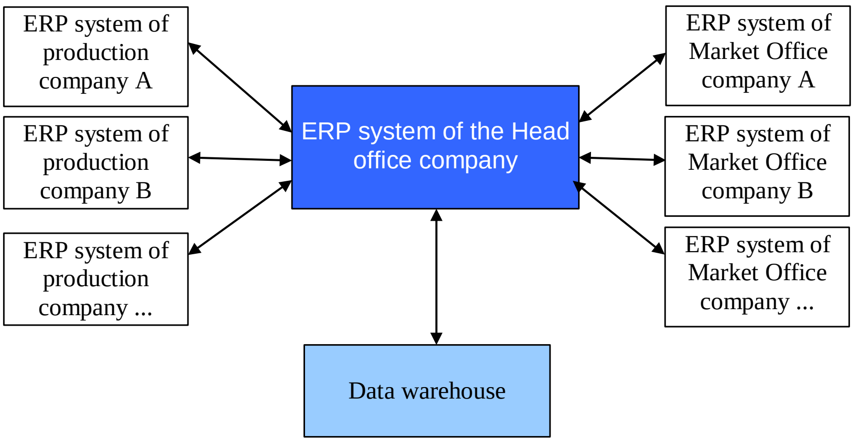


Fig. 1. ERP Network of a Conglomerate company

The notion of project management in manufacturing enterprises has been considerably consolidated for the last few decades. Project management has justified itself as a successful discipline of planning, organizing and managing resources to achieve desirable business objectives. The scope of objectives varies with the size and capabilities of a firm. Some firms focus on achieving single project realization, whereas others deploy a series of projects in order to obtain high and strategically important results. For this purpose they manage a portfolio, which combines a variety of projects united with a global objective. In that context, the issue of resource allocation among a number of projects arises. Therefore, the success of the project portfolio within a defined budget, aimed timeline, and constrained resources depends upon how the latter will be rationally allocated.

One of the challenges in project portfolio management is accurate predication of cash flow. Today SME-s are looking for solution, which enables to track and manage cash flow in collaborative conglomerate company. This is a main reason why this research was conducted. Particularly, lack of data required for reliable cash flow analysis needs to be resolved. Before IDSS could be used for cash flow management purposes we need reliable data from ERP system. Due to lack of useful data, a common practice is to collect manually from suppliers, which is very time-consuming and depends on how well suppliers' behaviors.

Here we consider only cash as the resource in studying cash flow, which of course is just one component among many others such as manpower, machines, materials, and so forth. Nevertheless cash flow in a project portfolio reflects the real wealth generated for shareholders. It also reveals further business availabilities such as reinvesting cash back on projects or claiming all returns and out of business.

In directing or managing projects, the overriding objective has often been to complete projects as soon as possible. The management of cash flows in such instances has assumed only secondary or tertiary importance over other project scheduling objectives such as minimizing project duration. Financial managers, on the other hand, and especially those whose primary responsibilities lie in the capital budgeting area, have indicated for years that project managers need to consider explicitly financial implications when managing a project [1].

Cash flow management is a complex and important problem faced by companies of different sizes, by governments and by individuals, usually requiring distinct approaches and proper tools according to the nature and complexity of the operations [3]. Cash flow forecasting and control are essential for the survival of any contractor. The main input data required to forecast cash flow for individual projects are operating costs, clients' payments and the time lag between disbursements and receipts [2]. The key criteria of cash flow forecasts include how accurate, flexible, and comprehensive they are calculated and how effectively uncertain factors are considered, such as time delay, cost overrun, variation of cost, and earned value between plan and reality.

In this paper, we describe a generic approach for integrated decision support in IDSS. The major contribution is the development of a concept for cash flow dynamics model which can be plugged into IDSS systems. It allows for real-time cash flow tracking and enables cash flow management decision support, which existing ERP systems for small and medium enterprises do not have.

In Section 2, the critical aspects of manufacturing project portfolio management are introduced, including project cost estimation and risk management. Section 3 introduces how cash flow management process can be supported by IDSS system. The new framework of cash flow management process flow is presented. The novel way to manage project cash flow dynamics using the Bernoulli principle of fluid dynamics is proposed in Section 4. We present the novel application of ENPV calculation. We use this approach for the assessment of alternatives in the case of the negative cash flow. Sensitivity analysis is used to select the solution with the minimal risk. This approach allows us to select the most reasonable decision.

2. PROJECT PORTFOLIO MANAGEMENT

It is important to distinguish between project portfolio selection and project portfolio management. The former is primarily concerned with the processes used by firms to include projects in the portfolio. The latter is the day-to-day management of the portfolio, including the policies, practices, procedures, tools, and actions that managers take to manage resources, make allocation decisions, and ensure portfolio successful performance.

In our paper we assume that the project portfolio has already been defined and the only concern is to distribute resources (including renewable and periodically generated), i.e., cash flow streams among the projects. Continuously tracking cash flow in and out of projects allows mitigate serious budget shortcomings. Keeping track of portfolio cash flow on a regular basis puts managers on alert for upcoming opportunities or threats with the projects months ahead. Managers are able to predict whether they need to increase cash flow into the projects or they could withdraw excessive cash flow out of the projects and then to reinvest it.

In manufacturing firms with multi-project or project portfolio management, the problem of optimal resource allocation is important because of the necessity to distribute the same type of limited resources among different projects. It demands a constant attention from the managers who have to deal with re-allocation of resource in short periods.

2.1. PROJECT COST ESTIMATING

Cost estimating is one of the most important steps in project management. A cost estimate establishes the base line of the project cost at different stages of development of the project.

Take facility design as an example. If the design technology for a facility has been specified, the project can be decomposed into elements at various levels of detail for the purpose of cost estimation. For design estimates, the unit cost method is commonly used when the project is decomposed into elements at various levels of a hierarchy as follows:

- *Cost Baseline*

The cost baseline is the time-phased budget that is used as a basis against which to measure, monitors, and control overall cost performance on the project. It is developed by summing estimated costs by period and is usually displayed in the form of an S-curve, as illustrated in Figure 1.

The cost baseline is a component of the project management plan. Many projects, especially large ones, have multiple cost or resource baselines, and consumables production baselines (e.g., tons of concrete per day) to measure different aspects of project performance.

Funding usually occurs in incremental amounts that are not continuous therefore appears as a step function in Figure 2. The total funds required are those included in the cost baseline plus the management contingency reserve amount. Some portion of the management contingency reserve can be included incrementally in each funding step or funded when needed, depending on organizational policies.

It is well known that investment analysis tools such as payback period (PP), return on assets (ROA), and simple return on investment (ROI) are weak because they do not take the time value of money into consideration [10]. That is, they do not consider the effect of inflation, which can have a significant impact on the results of the analysis. The investment analysis tool that considers the time value of money is net present value (NPV) analysis. However, NPV typically does not consider all the factors affecting the system.

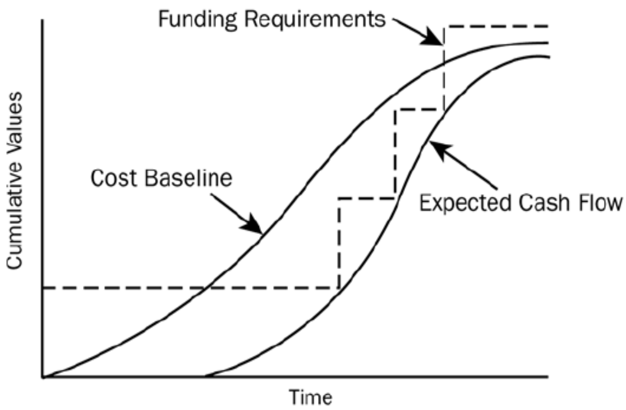


Fig. 2. Cash Flow, Cost Baseline and Funding Display

NPV is the sum of the ''real'' cash flows from a project over time. This is expressed mathematically as $NPV = \sum_{t=0}^{n} CF_t \big/ (1+i)^t$, where $CF_t = CF_{b,t} - CF_{c,t}$, $CF_{b,t}$ is the cash flow of benefits at time *t*; $CF_{c,t}$ is the cash flow of costs at time *t*; and *i* is the cost of capital (i.e., the annual interest rate). Projects with the largest NPV are approved first. NPV analysis does consider the time value of money as it provides results in deflated dollars (or as economists say, ''real'' or ''current'' dollars).

Expected net present value (ENPV) analysis offers the practitioner a more realistic approach to project evaluation and selection. Flaig [9] proposed to calculate ENPV values for project value estimation, which takes into accout of time value of money adjustment factor, ENPV, and cumulative expected net present value for periods 0 to *t*. Here we apply this solution for project portfolio, due to the reason that most of manufacturing enterprises work with a portfolio with multiple projects.

2.2. RISK MANAGEMENT FOR POJECT PORTFOLIO

Risk management is a necessary ingredient in any project. An organization can rate risks separately for each objective (e.g., cost, time, scope, and quality). In addition, it can develop ways to determine one overall rating for each risk. Project risk is an uncertain event or condition that, if it occurs, has a positive or a negative effect on at least one project objective, such as project delivery in accordance with the agreed-upon schedule and within the agreed-upon cost. A risk may have one or more causes and, if it occurs, one or more impacts. For example, being required to apply for an environmental permit to do work, or having limited personnel assigned to the project. The corresponding risk events are that the permitting agency may take longer than planned to issue a permit, and the personnel available and assigned may not be adequate for the activity. If either of these uncertain events occurs, there may be an impact on the project cost, schedule, or performance. Risk conditions could include aspects of the project's or organization's environment that may contribute to project risk, such as poor project management practices, lack of integrated management systems, concurrent multiple projects, or dependency on external participants who cannot be controlled.

A systematic structure that ensures a comprehensive process of identifying risks to a consistent level of detail is needed. This contributes to the effectiveness and quality of risk identification. A risk breakdown structure (RBS) as in Fig. 3 is one approach to provide such a structure. Risk identification can also be addressed by simply listing the various aspects of the project.

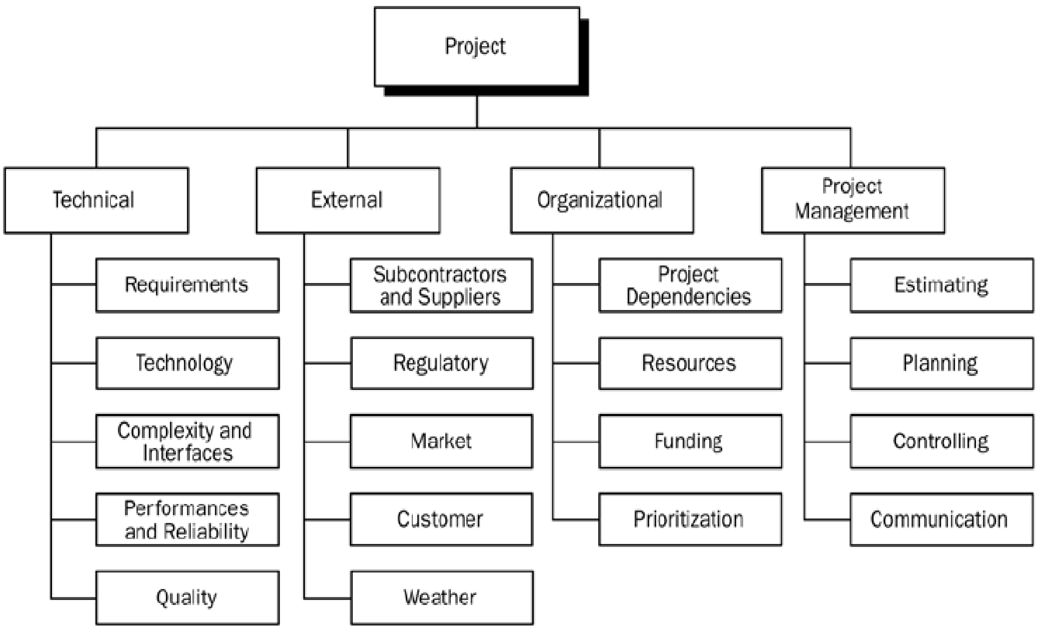


Fig. 3. Example of a Risk Breakdown Structure [7].

Risk can be estimated as:

$$risk = probability\ of\ event \times cost\ of\ event \quad (1)$$

Risk analysis forms the basis for risk management and crisis prevention. Here the emphasis is on cost effectiveness. Risk management involves adapting the use of existing resources, contingency planning and good use of new resources.

So far the research on portfolio management has been overwhelmed by issues concerning prioritization of projects and, distribution of resources from one project to another and the search for slack resources [5]. Here we present a new concept of project portfolio model that enables to allocate capital resources among in-progress projects. This project portfolio model is to be integrated with an IDSS environment.

3. IDSS FOR SUPPORT CASH-FLOW MANAGEMENT PROCESS IN NETWORK OF ENTERPRISES

Since cash flow management cannot be supported by ERP systems additional development should be performed. The new ERP system we are developing contains various enhancements, including:

- The system supports the complicated payments case. It tracks when the next payment part should be done and due date.
- It shows the prepayments that should be done before the producer starts the production.
- It allows to insert the agreed payment terms for each particular project, which will rewrite the payment terms on customer card
- The payment terms will be taken from particular Purchase order.
- The system allows to input update of due dates agreed with customers. It shows realistic cash flows on time and to have more precise predicted cash flow.

We propose a model of cash-flow management process starting from budget up to the tracking of real time cash-flow. As shown in Fig. 4, the model for cash flow planning and tracking is used for tracking purposes and calculation of ENPV, which estimates all possible solutions.

Enterprise network needs to ensure the positive cash flow. It is one of the key factors for the successful everyday operation of enterprise. When we start new manufacturing project, we have to make certain investments before we will be able to achieve any income. At the beginning we start with the financial forecast where the cash flows of future period are predicted. Here the probabilities of project realization are taken into account, which enables us to predict the total future cash flow.

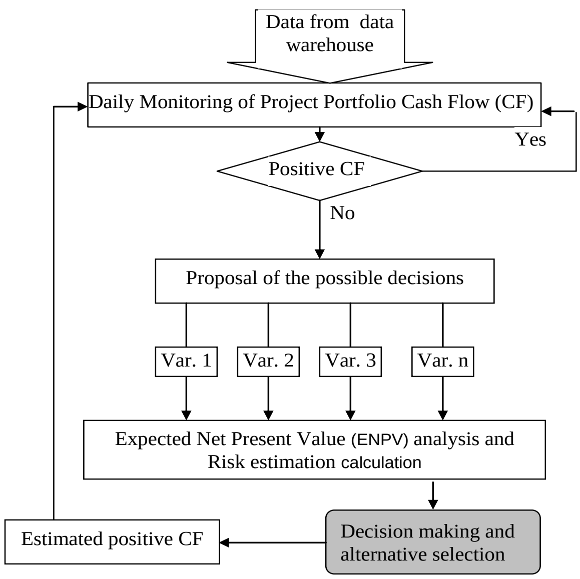


Fig. 4. Cash Flow management decision making process supported by IDSS

The strength of the proposed framework is the improvement of cash flow management of project portfolio.

The weakness is that at the beginning several development projects should be made in existing ERP systems in order to have data acquired.

4. MONITORING OF PROJECT PORTFOLIO CASH FLOW

Here, we propose a novel way to manage project cash flow dynamics using the Bernoulli principle of fluid dynamics. The idea of modelling financial cash flows through fluid alike motion recently attracted attentions. It was applied in studying financial markets, where the financial turbulence is described by laws from fluid dynamics. Los (2001) reformulated the classical laws of fluid mechanics for cash flow mechanics in order to measure and simulate various degrees of financial liquidity/illiquidity. He interpreted the laws of conservation of mass as conservation of investment capital, momentum as cash flow rate, and energy (with coefficient of two) as cash return. Further, a Bernoulli equation for cash flows was formulated to quantify the concept of financial pressure [8].

In our case, we use the Bernoulli's principle to model cash flows of project portfolios. Suppose a company has a portfolio of projects A, B and C (Table 1). The expected cash flows for each project are presented in Table 2.

Table 1. Manufacturing project portfolio of conglomerate company.

IDSS Input data for ENVP calculation	
Revenue (EUR/unit)	100 of Project A; 80 of Project B; 75 of Project C.
Interest rate (i)	8%
Periods per year	12 (monthly)
Volume (units/period)	100 Project A; 80 Project B; 75 Project C.
Number of employees	2 people in Project A; 3 people in Project B; 2 people in Project C.
Initial investment (EUR)	2000 in Project A; 1200 in Project B; 2200 in Project C;
Completion target	6^{th} period Project A; 8^{th} period Project B; 11^{th} period Project C.
Tolerance about target	1 period Project A: 0,5 Project B; 0,3 Project C.
Labour cost (EUR/period/employee)	2000
Material cost(EUR/unit)	50 Project A; 45 Project B; 40 Project C.

Table 2. Planned Cash Flow by period

End of period	CFt1	CFt2	CFt3	Cash
1	-2000	0	0	-2000
2	800	0	0	-1200
3	800	0	0	-400
4	800	0	0	400
5	800	-1200	0	0
6	800	2000	0	2800
7	0	2000	-2200	2600
8	0	0	1494,6	4094,6
9	0	0	1494,6	5589,2
10	0	0	1494,6	7083,8
11	0	0	0	7083,8
12	0	0		7083,8

The Bernoulli's principle is equivalent to the principle of conservation of energy, which states that the total amount of energy in an isolated system remains constant. The consequence of this law is that energy cannot be created or destroyed [12]. In our case, the cash flows of the constituent projects have the same total effect on the whole portfolio, as the result of the principle of conservation of value. Hence, the sum of profits in projects equals the total profit in portfolio, as illustrated in Fig. 5. The strong side of this solution is convenient way the projects portfolio can be tracked. The main disadvantage is the visibility of this solution if the amount of project in the project portfolio will be growing.

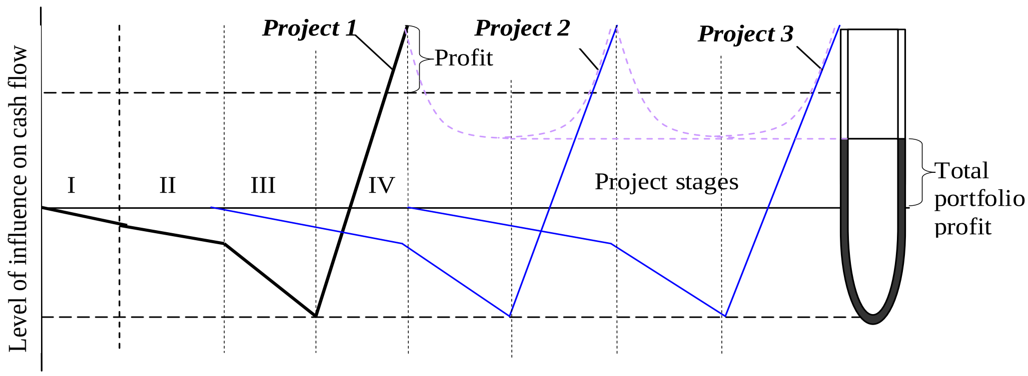


Fig. 5. Influence of cash flow on project stages

4. 1. ASSESMENT OF ALTERNATIVES IN CASE OF NEGATIVE CASH FLOW

Based on the proposed cash flow model, an IDSS system can track cash flows and give alert if a flow becomes negative. It can also be adjusted additional alert for case when the actual cash flow differs from the predicted one. The IDSS system can use the ENPV in prediction. The decision maker can compare the planned ENPV of project portfolios with the newly predicted value to make reliable decisions.

For our case study we have input information about project portfolio and predicted ENPV for this project portfolio. In case that we have any negative cash flow, the project should be delayed, which causes the delay of the second and third projects. The total ENVP of the project portfolio is then changed. The IDSS is able to calculate the predicted ENVP for every possible decision and help to find out the most reasonable decision that should be made in such situations. The possible decisions are:

a. We are taking a large loan from banks in order to compensate the negative cash flow of the first project. In this case we can eliminate the negative cash flow and can continue with project portfolio as it was previously planned (Table 3).
b. The second alternative is to take smaller loans from banks, in order to minimize the interest payments part. We may correct the project 1 plan and reschedule the project 2 if we can achieve such agreement with customer (Table 4).
c. We have a similar situation as in the second one. But the customer of project 3 does not agree with the project delay and cancel the project order. We take small loans, make corrections of project 1, and cancel project 2 (Table 5). The IDSS system is able to calculate the ENPV for every case (Table 6).

Table 3. Alternative 1

End of period	CFt1	CFt2	CFt3	Cash
1	-2000	0	0	-2000
2	11800	0	0	9800
3	-9480	0	0	320
4	520	0	0	840
5	520	-1200	0	160
6	520	2000	0	2680
7	-1000	2000	-2200	1480
8	0	0	1494,6	2974,6
9	0	0	1494,6	4469,2
10	0	0	1494,6	5963,8
11	0	0	0	5963,8
12	0	0	0	5963,8

Table 4. Alternative 2

End of period	CFt1	CFt2	CFt3	Cash
1	-2000	0	0	-2000
9992	800	0	0	-1200
3	-133,333	0	0	-1333,33
4	666,6667	0	0	-666,667
5	666,6667	0	0	0
6	666,6667	0	0	666,6667
7	10666,67	0	-2200	9133,333
8	-10000	0	1494,6	627,9333
9	0	0	1494,6	2122,533
10	0	-1200	1494,6	2417,133
11	0	2000	0	4417,133
12	0	2000	0	6417,133

Table 5. Alternative 3

End of period	CFt1	CFt2	CFt3	Cash
1	-2000	0	0	-2000
2	800	0	0	-1200
3	-133,333	0	0	-1333,33
4	666,6667	0	0	-666,667
5	666,6667	0	0	0
6	666,6667	0	0	666,6667
7	10666,67	0	-2200	9133,333
8	-10000	0	1494,6	627,9333
9	0	0	1494,6	2122,533
10	0	0	1494,6	3617,133

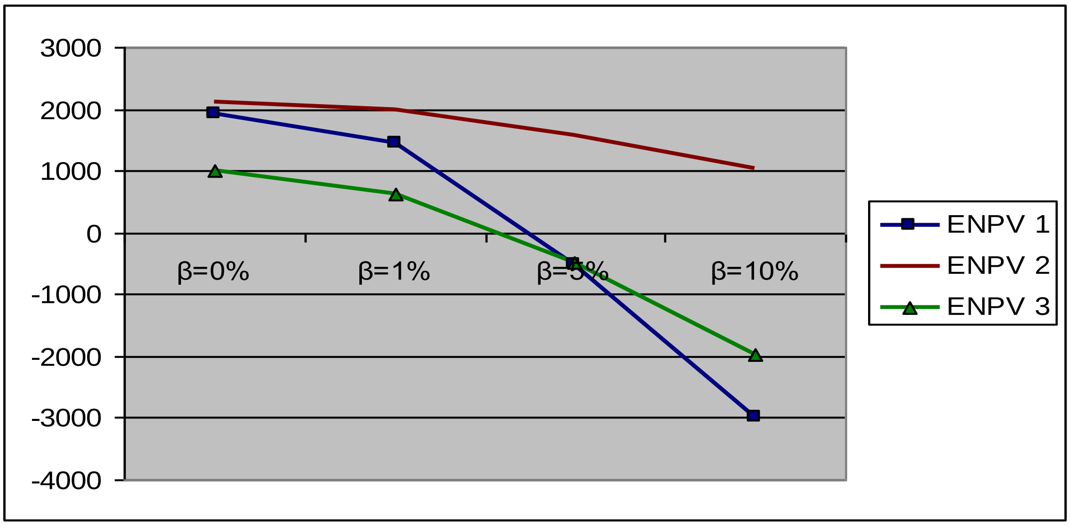
Table 6. Analysis of possible solutions by IDSS

Case study projects	Total ENPV
AS IS	6715,39
Case A	5721,42
Case B	6026,59
Case C	3436,30

4.2. RISKS ASSESMENT

The common approach is to make single "best estimates" for each of the uncertain factors and then to calculate measures of profitability such as ENPV or rate of return for the project. This approach has two drawbacks. (1) There is no guarantee that the "best estimates" will ever match actual values. (2) There is no way to measure the risk associated with the investment or the project risk. In particular, the manager has no way of determining neither the probability that the project will lose money nor the probability that it will generate considerable profits.

Sensitivity analysis is considered in order to indicate how much ENPV of the projects will change in response to a given change in an input variable [11]. Profitability in manufacturing is greatly influences by current market situation. Therefore, the variation in demand represents a key uncertainty. As a variable we use a number of sold items, what is characterized by market risk (beta risk). Fig. 6 demonstrates the project's NPV dependency on market risk, where β=5% means that sales decrease by 5 percents.



	B=0%	β=1%	β=5%	β=10%
ENPV 1	1924	1433	-529	-2981
ENPV 2	2113	1977	1570	1028
ENPV 3	1004	633	-478	-1960

Fig. 6. Sensitivity analysis of the projects' ENPV

The results of the sensitivity analysis show that the expected NPV of Project 1 has the highest dependency on market risks, i.e. it has steepest curve. Project 3 has the most stable ENPV (steady curve). This analysis helps prioritize projects in terms of their ENPVs and sensitivity on changes of variables. Here we can say that project 2 is less risky, so it is reasonable to apply it in our portfolio.

5. CONCLUSIONS

In this paper we presented the idea of project portfolio cash flow management supported by IDSS systems. The IDSS is able to assist decision makers in major capital investments such as the introduction of new products, which requires cash flow information over the life of the project. The investment profitability estimation depends on cash flow estimations, which are generally uncertain. Many cash flow elements (such as demand) are subject to substantial uncertainties. The proposed solution enables real time tracking of project cash flows. It makes the ENPV calculation for alternative assessments and risk calculation possible. The case study helps to understand how the proposed methodology could be used. Yet there are several limitations, such as indifference to the strategy of the company (i.e., a project could have worse expected NPV but it could bring more value in the long-term), the proposed method is still deterministic and it does not include in calculations the uncertainty in the future cash flows. Also it is practically difficult to track cash flow sequence of the different projects and the main constraint that all projects should be performed simultaneously.

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REFERENCES

[1] BAROUM S.M., PATTERSON J.H., *The development of cash flow weight procedures for maximizing the net present value of a project.* Journal of Operations Management, Volume 14, Number 3, September 1996.
[2] KAKA A. P., PRICE A. D. F., *Modeling standard cost commitment curves for contractors' cash flow forecasting* Construction Management and Economics, Volume 11, Issue 4 July 1993.
[3] BARBOSAP., PIMENTEL P., *A linear programming model for cash flow management in the Brazilian construction industry.* Construction Management and Economics (2001) 19, 2001, 469-479.
[4] KRAMARENKO S., SHEVTSHENKO E., KARAULOVA T., WANG Y., *Decision Analysis in Project Management Process.* Journal of the Machine Engineering, Wroclaw, Poland v.8, No.1, 2008.
[5] ENGWALL M., JERBRANT A., *The resource allocation syndrome: the prime challenge of multi-project management*.2003 International Journal of Project Management, Volume 21, Issue 6, 2003.
[6] HENDRICKSON C., *Project Management For Construction Fundamental Concepts For Owners*, Engineers, Architects And Builders Prentice Hall, ISBN 0-13-731266-0, 1989.
[7] PMBOK., *A Guide to the Project Management Body of Knowledge Third Edition* an American National Standard ANSI/PMI 99-001-2004.
[8] CORNELIS A. LOS., *Measuring financial cash flow and term structure dynamics*,2001.
[9] FLAIG J., *Improving Project Selection Using Expected Net Present Value Analysis* (2005). Quality Engineering, Taylor & Francis Inc. ISSN: 0898-2112.
[10] BLANCHARD B. S., FABRYCKY W. J., Systems Engineering and Analysis. Englewood Cliffs, NJ: Prentice-Hall, 1990.
[11] BRIGHAM E., GAPENSKI L., EHRHARDT M., *Financial management: theory and practice, 9th Ed. The Dryden Press*,1999.
[12] MUNSON B., YOUNG D., OKIISHI T., *Fundamentals of fluid mechanics, 3rd Ed.,* Wiley,ISBN 0471170240, 1998.