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Selection of the Desirable Project Roadmap Scheme, Using the Overall Project Risk (OPR) Concept

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1. Introduction

The findings of researches in the state-of-the art suggest that most errors are due to poor planning of project particularly early in the life of a project. Indeed, project success is positively correlated with the investment in requirements' definition and development of technical specifications (Dvir et. al., 2003). On the other hand, regarding the current business environment of rapid change, one of the main advantages of applying a proactive strategy in planning of projects is the greater flexibility in the competition conditions.
In the strategic planning phase of a project, the below question is outlined to one of the most significant issues in project management:

Which project roadmap scheme (PRS) is the desirable option to execute the project?

The PRSs will be formed by alternative responses to the questions such as:
Which contractor is the desirable option to engineer a given discipline?
Which machinery is the desirable option to produce a given part?
Which technology is the desirable option to montage a given product?
Which supplier is the desirable option to supply a given material?
Evaluating the feasible PRSs is recognized to be a considerable component of a sound project management. An important approach to evaluate the PRSs is the risk efficiency concept, which was originally developed by Markowitz (2002) for managing portfolios of investment opportunities. According to Chapman & Ward (2003), the PRSs can be viewed in a portfolio analysis framework. In fact, each PRS can be considered as an individual project.
The approaches to the solution of the above question "which PRS is the desirable option to execute the project?" can be classified in six groups:

1. Profile and checklist methods,
2. Project scoring methods,
3. Financial measures,
4. Mathematical programming models,
5. Multi Criteria Decision Making (MCDM) models, and
6. Fuzzy approaches.

Project scoring methods do not necessarily ensure the quality of PRS selection, because they do not explicitly take into account PRS level considerations, such as multiple resource constraints and other project interactions. Too often, financial measures are made based solely on criteria such as Net present Value (NPV) and Internal Rate of Return (IRR). Mathematical programming models often solve an integer linear programming to determine the optimal composition of the options subject to resource and other constraints. MCDM models (Keeney & Raiffa, 1999), on the other hand, consider the multi-criteria project values. For data which cannot be precisely assessed, fuzzy sets (Zadeh, 1965) can be used to denote them. The use of fuzzy set theory allows us to incorporate unquantifiable information, incomplete information, non-obtainable information, and partially ignorant facts into the decision model. The first four approaches offer the ability to rate PRSs with a quantitative monetarily unit. Henriksen & Traynor (1999) found that decisions made by managers and those made by a multi-criteria decision making model differ. These differences reflect that such techniques typically do week in simulation of the reality about the projects. It seems the risky world about the projects is usually neglected during the evaluation. In most of the real-world problems, projects are multidimensional in nature and have risky outcomes and decisions and must consider strategy and multidimensional measures (Meade & Presley, 2002).

It is stressed that most significant risks will be subjected to quantitative risk analysis of their impact on project (Project Management Institute [PMI], 2008; United State Department of Energy [US DOE], 2005). Several quantitative models have been introduced to provide valuable predictions for decision-makers. The most common risk valuation technique is expert elicitation. Using this method, the magnitude of consequences may be determined, through the use of expert's opinions. This could be applied using techniques such as interviewing (PMI, 2008). Risks can be represented by probability distribution functions. According to Kahkonen (1999), probability distributions are not widely used, because they are perceived to unlink the assessment from every-day work of project managers. To avoid direct application of probability distributions, the point-estimates (Kahkonen, 1999) are developed such as the Program Evaluation and Review Technique (PERT). Also, Critical Chain Project Management (CCPM) uses the same statistical basis as PERT, but only uses two estimates for the task duration, which are the most likely and the low risk estimates. Many assessment approaches deal with cost and schedule separately in order to simplify the process. Despite this, approaches such as the proposed method by Molenaar (2005) consider both cost and schedule, although schedule modeling tends to be at the aggregate level. Another method to deal with uncertainty is contingency allowance that is an amount of money used to provide for uncertainties associated with a project. The most common method of allowing for uncertainty is to add a percentage figure to the most likely estimate of the final cost of the known works. The amount added is usually called a contingency (Thompson & Perry, 1994).

The present paper introduces a technique to identify the PRS efficient frontier and choose the desirable scheme. According to the introduced model, in responding the question of "which PRS is the desirable option to execute the project?" the decision maker wishes to simultaneously satisfy two objectives, time and cost, with considering positive and negative risks. Most often, these multi-objectives will be in conflict, resulting in a more complicated decision making task. For this purpose, a new modeling approach is proposed to estimate the expected impacts of project risks quantitatively in terms of the project cost and the project time. This framework incorporates Directed A-cyclic Graph (DAG) into the Overall Project Risk (OPR) concept.

2. The proposed modelling approach

Fig. 1 presents process of the proposed model including six phases. The proposed model is structured based on a screening mechanism including three filters as presented in Fig. 2.

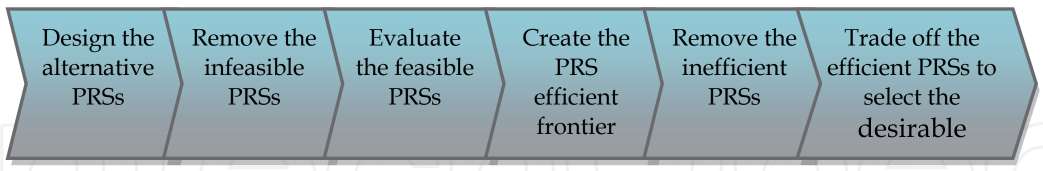

Fig. 1. Process of the proposed technique including six phases

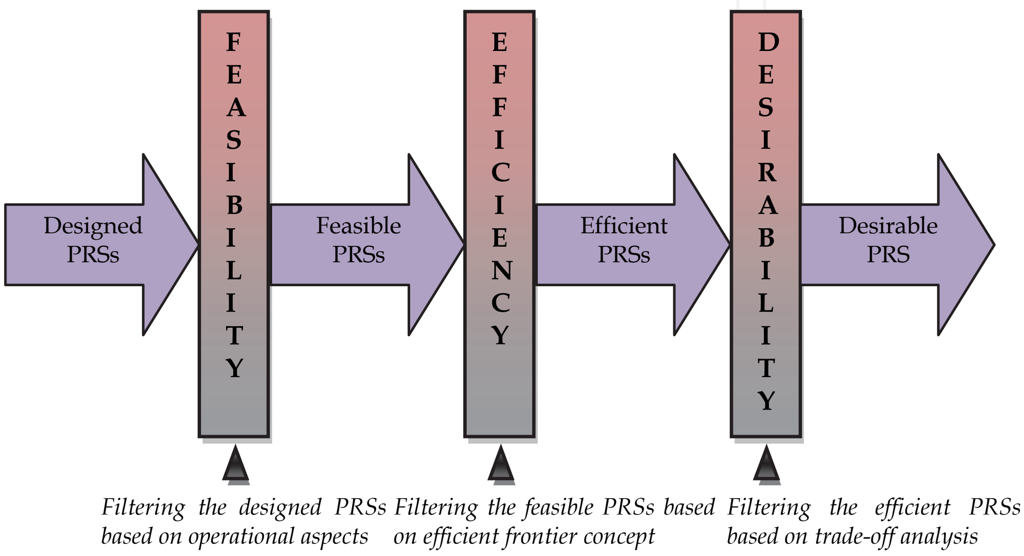

Fig. 2. Screening mechanism of the proposed model

2.1 Designing the alternative PRSs

In the first phase of the process, the project analysts consider different core managerial functions of project and, design the alternative PRSs. Core managerial functions in the field of business and strategic management are (Jaafari, 2007):

- Customers and markets,
- Stakeholders,
- Technology,
- Facility design and operational requirements,
- Supply chain system,
- Learning and innovation,
- Finance,
- Project delivery strategy,
- Risks and due diligence.

Besides, core managerial functions in the field of implementation management are:

- Governance and leadership,
- Engineering, detail design and specifications,
- Procurement, transportation and warehousing,

- Planning and control,
- Team performance,
- Information and communication management,
- Quality management,
- Offsite management,
- Risk management.

2.2 Removing the infeasible PRSs
Some of the designed PRSs may be operationally (technically, conceptually, socially, politically, etc.) inconsistent to implement, so should be removed from the candidate list. The following instances are some inconsistent cases which are experienced in real-world projects:
- An assumed material and a given processing technology may be technically inconsistent.
- Due to some political circumstances, two contractors may keep away to incorporate in a common partnership contract.
- An assumed agent who has not enough experiences should not be assigned for managing a discipline.
- A special mechanical tool may be infeasible to operate in a moist climate.

2.3 Evaluating the Feasible PRSs
In the third phase of the process, including computational core of the model, all of the feasible PRSs are separately evaluated. For a given PRS, it carried out the following stages as shown in Fig. 3:

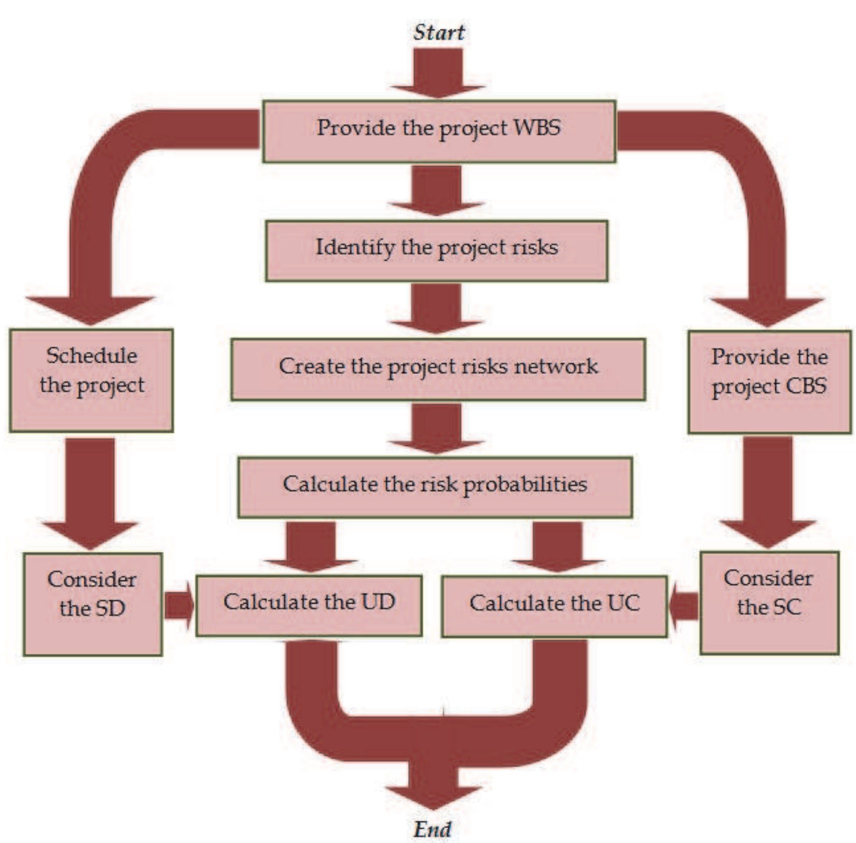

Fig. 3. The evaluation process of an individual PRS

Stage 1: Create the project Work Breakdown Structure (WBS): Complex projects can be overwhelming to the project managers. Instinctively, many project analysts break project down into smaller, more manageable parts. These decompositions are called breakdown structures (US DoE, 2005). WBS is a top-down hierarchical chart of tasks and subtasks required to complete project. WBS can focus on a product, a function, or anything describing what needs to be accomplished (PMI, 2008).

Stage 2: Schedule the project and, calculate Scope Duration (SD): A scheduling methodology defines the rules and approaches for project scheduling. Scheduling is carried out in advance of the project commencing and involves:

- Identifying the activities that need to be carried out;
- Defining activities dependencies which its result is the so called preceding or succeeding activity list.
- Drawing activities network which its result is a graphical portrayed set of activity relationships.
- Estimating how long the activities will take which its result is the so called activity duration.
- Allocating resources to the activities;
- Applying a technique to calculate the earliest/latest start and finish dates of each activity. The present model recommends the better known techniques include Critical Path Method (CPM) or Critical Chain (PMI, 2008).

After scheduling, the project aim on time (SD) will be obtained.

Stage 3: Create the project Cost Breakdown Structure (CBS) and, calculate Scope Cost (SC): The proposed model uses CBS to measure cost elements. Each item in WBS is generally assigned a unique identifier; these identifiers can provide a structure for a hierarchical summation of costs and resources (PMI, 2008). Therefore, CBS represents the hierarchical breakdown of the project costs, so CBS is derived from WBS. After establishing CBS, the target cost of project (SC) will be obtained.

Stage 4: Identify the project risk events: Risk event is an uncertain event or condition that, if it occurs, has a positive or negative effect on at least one project objective: scope, schedule, cost, and quality (PMI, 2008). In the proposed model, risks that have direct or indirect effects on the time and cost of project will be considered. For identifying the risks, the analyzer may benefit from typology of risks mapped in Risk Breakdown Schedule (RBS). For instance, the list below presents a useful typology of common project risks (Mc-Connel, 1996):

- Schedule creation risks such as "excessive schedule pressure reduces productivity".
- Organization and management risks such as "project lacks an effective management sponsor".
- Development environment risks such as "facilities are not available on time".
- End user risks such as "end user ultimately finds product to be unsatisfactory, requiring redesign and rework";
- Customer risks such as "customer has expectations for development speed that developers cannot meet ";
- Contractor risks such as "contractor does not buy into the project and consequently does not provide the level of performance needed";
- Requirement risks such as "vaguely specified areas of the product are more time-consuming than expected";
- Product risks such as "operation in an unfamiliar or unproved software environment causes unforeseen problems";

- External environment risks such as "product depends on government regulations, which change unexpectedly";
- Personnel risks such as "problem team members are not removed from the team, damaging overall team motivation";
- Design and implementation risks such as "necessary functionality cannot be implemented using the selected code or class libraries; developers must switch to new libraries or custom-build the necessary functionality";
- Process risks such as "management-level progress reporting takes more developer time than expected";

Stage 5: Create project risks network and, calculate risks probabilities: Two following criteria are used to characterize risks:

- Risk probability that is the probability of occurring risk event (Kerzner, 2009).
- Risk impact that is the impact of occurring risk event (Kerzner, 2009).

In the proposed model, risk impact reflects the magnitude of effects, either negative or positive, on SC and SD if a risk event occurs. For calculating the risk probability and the risk impacts, the model uses risks network that is a DAG with the following considerations:

i. DAG is a graph $G(N, A)$, where $N = \{E_1, E_2, \ldots, E_m\}$ is a finite set of nodes and $A \subseteq N \times N$ a set of arcs. Each node E_i $(i = 1, 2, 3, \ldots, m)$ refers to a risk event and each arc $(E_i, E_j) \in A$ indicates direct conditional dependencies between two risk events E_i and E_j . If two nodes E_i and E_j within arc (E_i, E_j) are ordered, then the arcs have a direction assigned to them. This is called a directed graph. For a given arc $(E_i, E_j) \in A$, the node E_i is called parent node and the node E_j is called child node.

ii. A conditional probability of P_{ij} which equals $P(E_j \mid E_i)$ is placed for each arc (E_i, E_j) . Also, for each node E_i a free probability P_i $(i = 1, 2, 3, \ldots, m)$ is dedicated that is the probability of its occurrence due to risk sources outside risks network. We assume that both P_i and P_{ij} are point estimates or the mean value of a Probability Density Function (PDF) provided by simulation techniques such as the Monte Carlo analysis (PMI, 2008).

iii. Risks network accepts only the acyclic relationships among the risk events. A cycle within a graph is a path that starts and ends at the same node.

Path is a sub-graph of risks network including series of nodes where each node is connected to another node by an arc and all connecting arcs are unidirectional. Each node can occur in the path once only. Each path starts with a source event and ends with a sink event. A path could be depicted as continuum $E_{i_1} \rightarrow E_{i_2} \rightarrow E_{i_3} \rightarrow \ldots \rightarrow E_{i_K}$. To simplify this continuum, it could be presented as $\overrightarrow{i_1 i_2 i_3 \ldots i_K}$. We also, denote a specific path as $Path_t$ $(t = 1, 2, 3, \cdots, T)$, which T is the number of the paths within risks network. All paths are placed in the set of R as (1).

$$R = \{Path_t \mid t = 1, 2, 3, \ldots, T\} \quad (1)$$

In a path, the first node is called source and the last node is called sink. As Eq. (2) and Eq. (3), the functions $Source()$ and $Sink()$ respectively indicates the source event and the sink event of a path.

$$Source(\overrightarrow{i_1 i_2 i_3 \cdots i_K}) = E_{i_1} \quad (2)$$

$$Sink(\overrightarrow{i_1 i_2 i_3 \cdots i_K}) = E_{i_K} \quad (3)$$

As Eq. (4) and Eq. (5) set S_i includes all the paths starting with risk event E_i and set F_i includes all the paths finishing with risk event E_i.

$$S_i = \{Path_t \mid Source(Path_t) = E_i, t = 1,2,3,\ldots,T_i\} \quad (4)$$

$$F_i = \{Path_t \mid Sink(Path_t) = E_i, t = 1,2,3,\ldots,T_i\} \quad (5)$$

As Eq. (6), the plus function $\oplus$ can be used to add a part to the end of a path.

$$(\overrightarrow{i_1 i_2 i_3 \ldots i_k} \oplus \vec{i}_{k+1}) = \overrightarrow{i_1 i_2 i_3 \ldots i_k i}_{k+1} \quad (6)$$

As in term (7) $Path_1$ is subset of $Path_2$, if $Source(Path_1)$ is equal to $Source(Path_2)$, and $Path_1$ contains the complete structure of $Path_2$.

$$\overrightarrow{i_1 i_2 i_3 \ldots i_{v-1} i_v i_{v+1} \ldots i_{K-1} i_K} \subseteq \overrightarrow{i_1 i_2 i_3 \ldots i_{v-1} i_v} \quad (7)$$

According to Eq. (8), each path has a probability, which is defined as the product of free probability of its source event and the conditional probabilities related to its arcs.

$$P(\overrightarrow{i_1 i_2 i_3 \ldots i_k}) = P_{i_1} \times P_{i_1 i_2} \times P_{i_2 i_3} \times \ldots \times P_{i_{K-1} i_K} \quad (8)$$

Probability of the intersection of some paths equals the product of the probabilities of these paths divided by probabilities of common source event or common arcs. Besides, probability of the union of the paths, simply, could be calculated using conventional set union function. As Eq. (9), the occurrence probability of an individual risk event E_i equals the probability of union of all the paths ending with this event. Also, as Eq. (10), the occurrence probability of at least one of the events equals union probability of all paths ending with these events. In addition, as Eq. (11), the occurrence probability of all of events equals intersection probability of all paths ending with these events. It should be noted that for the purpose of identifying the paths within risks network, a labeling algorithm is considered.

$$P(E_i) = P(\bigcup_{\forall Path_t \in F_i} Path_t) \quad (9)$$

$$P(\bigcup_{k=1}^{K} E_{i_k}) = P(\bigcup_{k=1}^{K} \bigcup_{\forall Path_t \in F_{i_k}} Path_t) \quad (10)$$

$$P(\bigcap_{k=1}^{K} E_{i_k}) = P(\bigcap_{k=1}^{K} \bigcup_{\forall Path_t \in F_{i_k}} Path_t) \quad (11)$$

For the purpose of identifying the paths within risks network, a labeling algorithm is considered as Fig. 4, in which F_i is the set of labels for E_i (see Eq. (5)); B_i is a binary index that equals zero until the algorithm completes labeling of risk event E_i. To create the label of a given risk event E_i, if $(E_j, E_i) \in A$, as term (12), the part " i " is added to the end of the labels for risk event E_j. The algorithm does create any labels for a risk event that its free probability is equal to zero.

$$F_i = F_i + \{Path_t \oplus \vec{i} \mid, Path_t \in F_j, \{j \mid (E_j, E_i) \in A\}\} \tag{12}$$

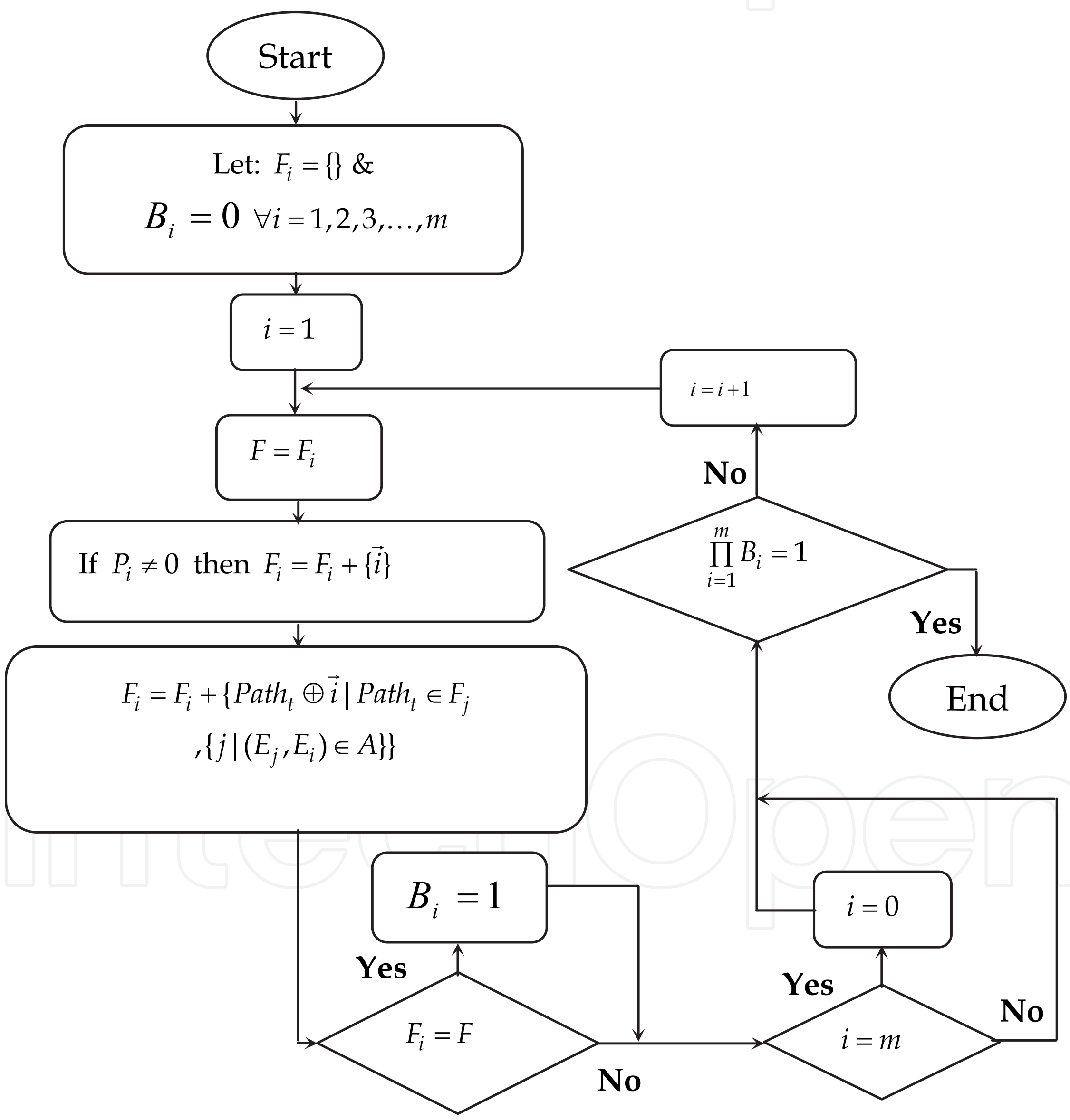

Fig. 4. The labeling algorithm to identify the paths within risks network

Stage 6: Calculate Ultimate Schedule (UD) & Ultimate Cost (UC): UC is the ultimate state of the project cost with considering risk events. UD is the ultimate state of the project duration with considering risk events. The project owners may be interested in knowing the total risk of their project. Indeed, it is often desirable to combine the various risk events into a single quantitative project risk estimate. This estimate is OPR that may be used as input for a decision about whether or not to execute a project, as a rational basis for setting a contingency, and to set priorities for risk response actions (US DOE, 2005). The proposed technique uses the OPR for calculating UC and UD. The main concept here is the relationship between two nodes connected with a direct arc in risks network. According to Fig. 5, the occurrence of a parent node E_i affects the occurrence of a child node E_j (forward circuit), consequently, the impacts of occurrence of the child node E_j, is also transferred to the parent E_i (backward circuit).

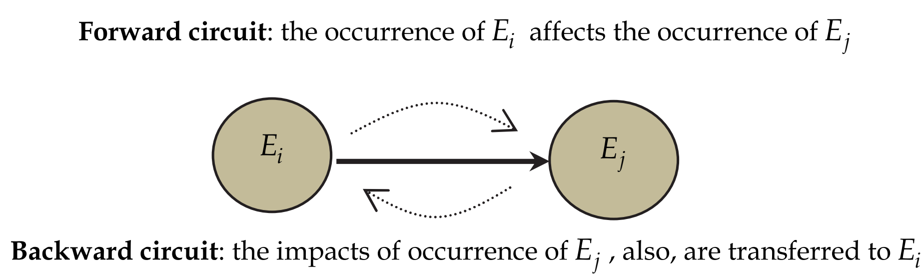

Fig. 5. Relationships between child and parent nodes of an arc in risks network

Assume that by use of a suitable level of CBS, the risk impacts on the project cost are as vector (13) that is named as Cost Impact Vector (CIV). It should be noted that each $C_j \in CIV$ is negative value for cost increscent (unwelcome) and is positive value for cost decrement (welcome). The risk analyst can establish the cost matrix (14) in which the rows indicate risk events and the columns stand for the elements of vector (13). The elements of cost matrix (14) are binary parameters c_{ij} as definition (15). Using CIV and cost matrix, UC could be calculated as Eq. (16).

$$CIV^t = \begin{bmatrix} C_1 & C_2 & \dots & \dots & C_c \end{bmatrix} \tag{13}$$

$$C = \left[c_{ij}\right]_{m\times c} = \begin{matrix} E_1 \\ E_2 \\ \vdots \\ E_m \end{matrix} \begin{bmatrix} c_{11} & c_{12} & \dots & c_{1c} \\ c_{21} & & & \\ \vdots & & & \vdots \\ c_{m1} & & \dots & c_{mc} \end{bmatrix} \tag{14}$$

$$c_{ij} = \begin{cases} 1 & \text{If occurring } E_i \text{ causes cost } C_j \\ 0 & \text{Otherwise} \end{cases} \tag{15}$$

$$UC = SC - \sum_{j=1}^{c} C_j \times P(\bigcup_{\{i|c_{ij}=1\}} E_i) \tag{16}$$

For calculating UD, let $N' \subseteq N$ contain all the risk events that affect the project scheduling. Consider the set β including all non-empty subset of $N' \subseteq N$ as Eq. (17). Now, for all $\beta_w \in \beta$ calculate Eq. (18) in which SD_w is the project duration for subset β_w. For calculating SD_w, we should consider the occurrence of all risk events $E_i \in \beta_w$. In Eq. (18), the second part $\ddot{P}(\bigcap E_i)$ indicates that all risk events $E_i \in \beta_w$ must have occurred. The double-dots sign on the top of this term means that before calculating this probability we are required to apply some conditions related to the third part of Eq. (18). For calculating $\ddot{P}(\bigcap E_i)$, temporarily remove all risk events in which $E_i \in N' \;\&\; E_i \notin \beta_w$. The third part of Eq. (18) indicates that all risk events in which $E_i \in N'$ and $E_i \notin \beta_w$ should not occur. Finally, UD could be calculated as Eq. (19).

$$\beta = \{\beta_w \mid \beta_w \subseteq N', w = 1,2,3,\cdots,W\} \tag{17}$$

$$\lambda_w = (SD - SD_w) \times \ddot{P}(\bigcap_{E_i \in \beta_w} E_i) \times 1 - P(\bigcup_{E_i \in N' - \beta_w} E_i) \quad \forall w = 1,2,3,\ldots,W \tag{18}$$

$$UD = SD - \sum_{w=1}^{W} \lambda_w \tag{19}$$

2.4 Creating the PRS efficient frontier

When evaluating a particular PRS in relation to alternative schemes, we can consider the project cost as the first basic measure of performance and the project time as the second one. The PRS efficient frontier is the set of the feasible PRSs that provides a minimum level of project time for any given project cost, or minimum level of project cost for any given level of project time. This concept is most easily pictured using a graph like Fig. 6. In this figure, B, C, D, E, F and G are the alternative feasible PRSs (schemes A and H are the infeasible PRSs which have been removed in the second phase of the process); the PRS efficient frontier is portrayed by the curve B-C-D-E.

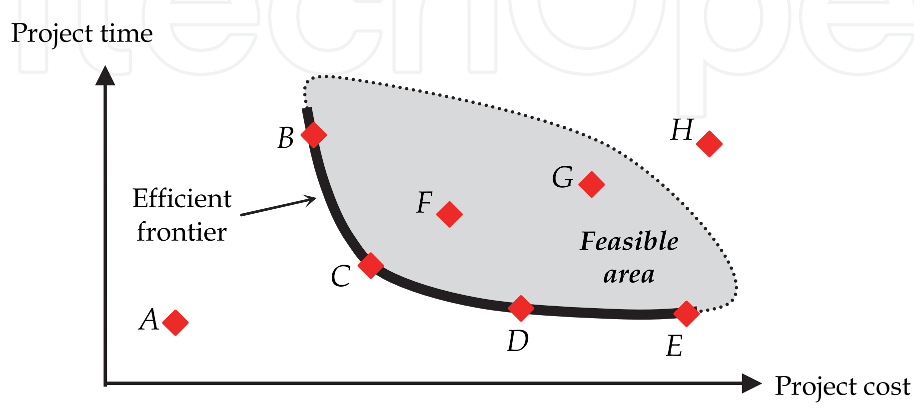

Fig. 6. The PRS efficient frontier concept

2.5 Removing the inefficient PRSs

In the 5th phase of the process, the entire inefficient schemes should be removed from the list of candidate PRSs. Regarding the above discussions in previous section, 2.4, any points inside the frontier, like F and G in Fig. 6, represent the inefficient PRSs. F is more efficient than G, but F can be improved on with respect to both project cost and project time (e.g. moving to C).

2.6 Trading off the efficient prss to select the desirable scheme

In the 6th phase of the process, the efficient PRSs should be pair-wise compared. In each pair-wise comparison, one of the PRSs is removed as Eq. (20). The parameter α is defined as the payment (dollars) that project owners will be admitted for one time-unit (i.e. 1 day) increment in the project duration. More α results in more importance of the project time than the project cost. Regarding Eq. (20), it should be noted that the desirable PRS is the nearest point to the tangent point between the PRS efficient frontier and the line by gradient $-\alpha^{-1}$.

$$\begin{cases} \text{If } \left(\dfrac{UC_i - UC_j}{UD_j - UD_i}\right) \le \alpha \text{ then} & \begin{cases} \text{If } UD_i \ge UD_j \text{ remove PRS \# } i \\ \text{If } UD_i < UD_j \text{ remove PRS \# } j \end{cases} \\ \text{If } \left(\dfrac{UC_i - UC_j}{UD_j - UD_i}\right) > \alpha \text{ then} & \begin{cases} \text{If } UC_i \ge UC_j \text{ remove PRS \# } i \\ \text{If } UC_i < UC_j \text{ remove PRS \# } j \end{cases} \end{cases} \quad (20)$$

3. Analytical results

For analyzing the model, we consider a project includes Engineering, Procurement, and Construction (EPC) of a powerhouse cavern elevator, which has been drawn from a hydro-mechanical power plant. The project includes four sub-products cabin, hoisting machine, suspension guides and control equipments.

The entire outputs of the process phases are at one glance mapped in Table 1 that presents that twelve PRSs were designed.

Phase 1: The project experts considered the following alternatives to design candidate PRSs. They designed twelve PRSs (see Table 1).

- Two alternatives for supplying the elevator cabin:
  - (a1) fabricating the cabin in the firm and then transporting it to the erection site;

- (a2) fabricating the cabin in the erection site.
- Three alternatives for supplying the elevator hoisting machine:
  - (b1) buying the hoisting machine from the foreign supplier 1;
  - (b2) buying the hoisting machine from the foreign supplier 2;
  - (b3) buying the hoisting machine from the present inside supplier.
- Two alternatives for basic designing the control equipment:
  - (c1) employing a sub-contractor for basic designing the control equipment;
  - (c2) buying a present basic design.

PRS code	PRS contents	Feasibility	UC ($)	UD (days)	Efficiency	Desirability
S1	(a1), (b1), (c1)	Feasible	148,900	540	Inefficient	-
S2	(a1), (b1), (c2)	Infeasible	-	-	-	-
S3	(a1), (b2), (c1)	Feasible	137,000	390	Efficient	Undesirable
S4	(a1), (b2), (c2)	Feasible	165,800	485	Inefficient	-
S5	(a1), (b3), (c1)	Feasible	125,975	525	Efficient	Undesirable
S6	(a1), (b3), (c2)	Feasible	192,900	340	Efficient	Undesirable
S7	(a2), (b1), (c1)	Infeasible	-	-	-	-
S8	(a2), (b1), (c2)	Feasible	158,800	350	Efficient	Desirable
S9	(a2), (b2), (c1)	Infeasible	-	-	-	-
S10	(a2), (b2), (c2)	Feasible	175,698	490	Inefficient	-
S11	(a2), (b3), (c1)	Feasible	138,000	500	Inefficient	-
S12	(a2), (b3), (c2)	Feasible	210,550	335	Efficient	Undesirable

Table 1. The designed PRSs for the typical project

Phase 2: The operational discussions about the feasibility of the schemes resulted in the schemes S2, S7 and S9 are not feasible to execute; consequently, these schemes were removed from the candidate list.
Phase 3: The nine feasible PRSs were evaluated. As a sample, table 2 exhibits the WBS, Fig. 7 shows the CBS and, Fig. 8 shows the risks network for PRS S4. According to Table 2, for PRS S4, SC=137,700 $ & SD=420 days; by considering the occurrence of the risk events, UC=137,700 $ and UD=485 days (see Table 1). Table 1 shows UC and UD for the nine feasible PRSs.
Phase 4: The nine feasible PRSs have been portrayed in Fig. 9.

No.	WBS code	Activity	Duration (days)	Cost ($)
1	**1**	**Powerhouse cavern elevator**	420	137,700
2	**1.1**	**Cabin**	420	56,000
3	1.1.1	Designing	44	9,000
4	1.1.2	Material supply	90	23,000
5	1.1.3	Manufacturing & Assembly	310	4,000
6	1.1.4	Transportation to erection site	10	2,000
7	1.1.5	Erection	40	18,000
8	**1.2**	**Hoisting machine**	**401**	**29,500**
9	1.2.1	Designing	37	6,600
10	1.2.2	Material supply	110	12,800
11	1.2.3	Manufacturing & Assembly	50	2,200
12	1.2.4	Transportation to erection site	17	1,300
13	1.2.5	Erection	20	6,600
14	**1.3**	**Suspension guides**	**381**	**48,000**
15	1.3.1	Designing	60	4,200
16	1.3.2	Material supply	115	2,600
17	1.3.3	Manufacturing & Assembly	155	19,200
18	1.3.4	Transportation to erection site	19	1,400
19	1.3.5	Erection	32	9,600
20	**1.4**	**Control equipment**	**240**	**21,800**
21	1.4.1	Designing	35	3,200
22	1.4.2	Material supply	100	5,100
23	1.4.3	Manufacturing & Assembly	75	4,500
24	1.4.4	Transportation to erection site	15	1,100
25	1.4.5	Erection	15	1,300

Table 2. The project WBS including durations and costs for PRS S4

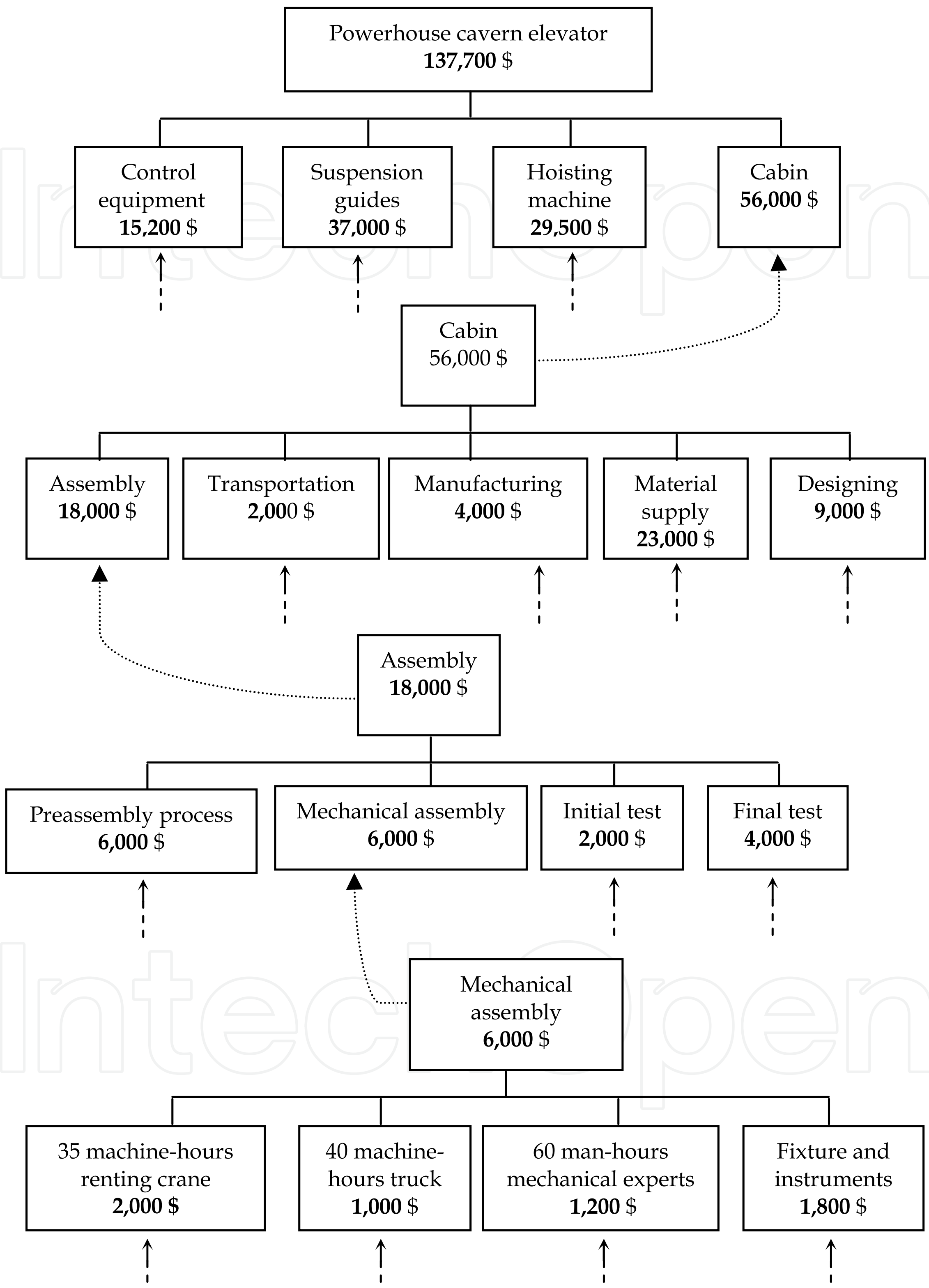

Fig. 7. A part of the CBS for PRS S4

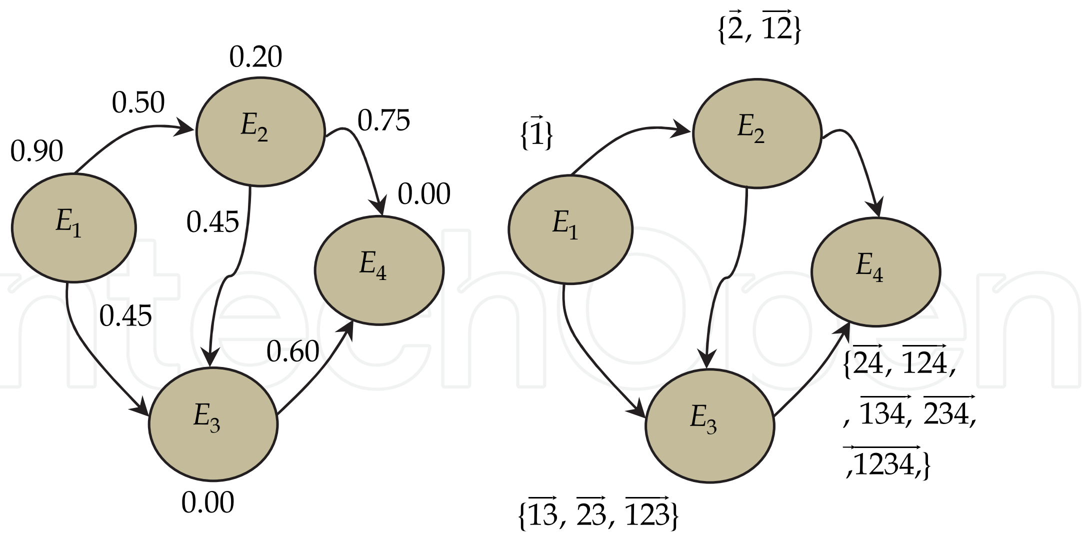

Fig. 8. The risks network for PRS S4 (left) and its labels (right)

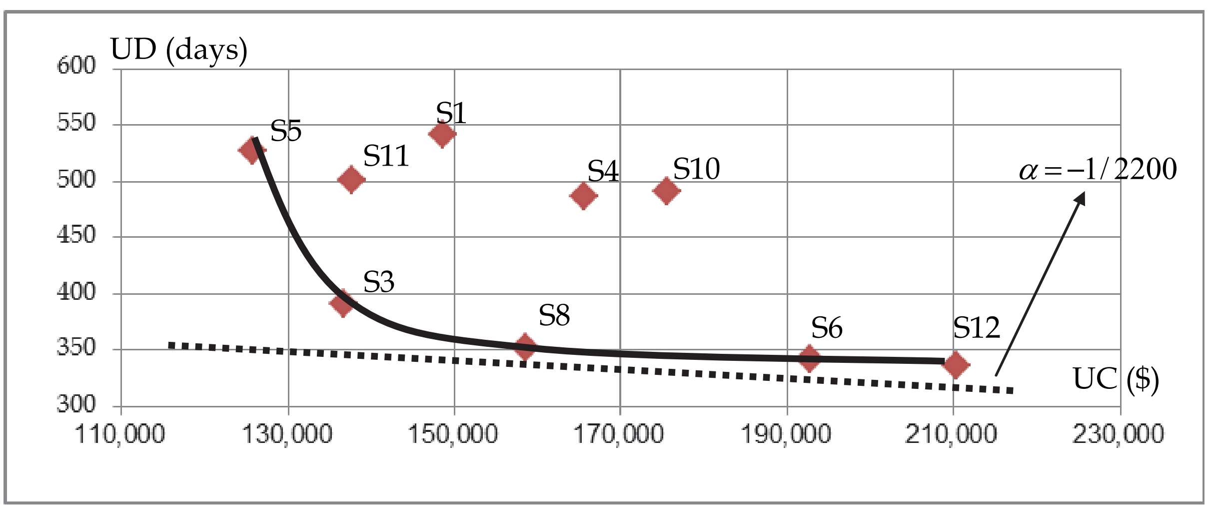

Fig. 9. The PRS efficient frontier for the typical project

Phase 5: The schemes S1, S4, S10 and S11 were considered as the inefficient PRSs and were removed from the candidate list of the PRSs.
Phase 6: For choosing the desirable PRS among the reminded schemes S3, S5, S6, S8 and S12, the experts did the pair-wise comparisons as Eq. (19). By assuming $\alpha = 2200$ $/day, for instance the term ((158,800-137,000) / (390-350)) = 545 $/day was calculated for the pair-wise comparison between the schemes S3 & S8. Because $545 < \alpha$ & $350 < 390$ thus PRS S3 was removed; in pair-wise comparison between PRSs S6 & S8, because $3410 > \alpha$ & $158{,}800 < 192{,}900$ thus PRS S6 was removed; in comparison between PRSs S5 & S8, because $188 < \alpha$ & $350 < 525$ thus PRS S5 was removed and finally, in comparison between PRSs S8 & S12, because $3450 > \alpha$ & $158{,}800 < 210{,}550$ so PRS S12 was removed. Finally PRS S8 was considered as the desirable scheme. The selected scheme, PRS S8, contains fabricating the cabin in the erection site, buying the hoisting machine from the foreign supplier 1, and

buying a present basic design for control equipment. As it has been shown in Fig. 9, the PRS S8 is the nearest point to the tangent point between the efficient frontier and the line with gradient-1/2200.

4. Discussions

Several characters of the proposed model are worthwhile emphasizing:

- The risk researchers believe that project risk analysis should be strongly integrated to the project elements (Chapman & Ward, 2003; Kerzner, 2009; Seyedhoseini et. al., 2008a, 2008b; Ward & Chapman, 2003). In our approach, WBS plays a central role in the quantification of risks. So, the main contribution of the proposed technique is in demonstrating how overall project plan and project risk analysis could be integrated through a united framework. It should be explained that a common technique in estimating the risk probability and risk impact is the use of scales that are usually quantified directly through the expert elicitation. We believe that there is a gap between the scale tablets and the expert's opinion. The proposed model acts a means for bridging the mentioned gap.
- Another key feature of the model is explicitly allowing for dependency relationships among risk events. This is made possible by using DAG.
- The model considers both upside and downside risks within a united perspective. Therefore one can observe that this perspective is a step toward the uncertainty management (Ward & Chapman, 2003).
- Regarding the project environment, since no data record was available about project risk analysis in previous similar projects, probability distribution elicitation for task duration or cost may be difficult for projects, which in turn could limit the applicability of techniques. According to Chapman & Ward (2003), too often this precision is false, because the initial data may be too vague to be fitted into a probability function or the assumptions behind the distributions do not hold true. So, in the proposed technique, all of input data to the model is considered to be one-point estimates. These estimates are easy to understand (Kahkonen, 1999), and do not include a range of values, standard deviation and variance, or confidence intervals, so they do not include the effects of uncertainty and are simply based on the summation of a number of point estimates for items of work.

The technique presented here can be expanded to allow for additional features of the problem.

- Based on the two-polar concept of project risk management (Seyedhoseini et al., 2008a), one such extension is considering the implementation of risk response actions to calculate UC and UD that results in more effective the technique.
- Another extension of the model aims to address the cyclic dependencies among the risk events. Naturally when cyclical feedbacks are considered, it is more difficult but more useful.
- Finally we recall that the proposed model does not guarantee the inclusion of the quality aspects of project. It could be worthwhile to investigate the risk impacts on the project quality. Regarding this area, the reader is encouraged to study work of Seyedhoseini et al. (2008b).

5. Conclusion

Most of the real-world projects are multidimensional in nature and include many risky phenomena, while in the state-of-the art of Project Roadmap Scheme (PRS) selection, risks are usually neglected. In this chapter, we proposed a risk-based modeling approach to support evaluating the alternative PRS and choosing the desirable scheme. In the proposed model, the PRSs are designed then, within a screening mechanism including three criteria of feasibility, efficiency and desirability are filtered. The project cost and the project time play a central role to identify the PRS efficient frontier. The chapter also introduced the development and application of Directed Acyclic Graph (DAG) for estimation of the expected impacts of the project risks. The main contribution of this research was in demonstrating how project plan and Overall Project Risk (OPR) could be integrated through a united framework. We conclude that applying the proposed model helps the project experts to evaluate the feasible PRSs and to choose the desirable scheme in most effective and productive manner dealing with in real world's uncertainties.

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In many human activities risk is unavoidable. It pervades our life and can have a negative impact on individual, business and social levels. Luckily, risk can be assessed and we can cope with it through appropriate management methodologies. The book Risk Management Trends offers to both, researchers and practitioners, new ideas, experiences and research that can be used either to better understand risks in a rapidly changing world or to implement a risk management program in many fields. With contributions from researchers and practitioners, Risk Management Trends will empower the reader with the state of the art knowledge necessary to understand and manage risks in the fields of enterprise management, medicine, insurance and safety.