

Pipeline Risk Management Framework

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Abstract—A knowledge-based expert system with the acronym RASPE is developed as an application tool to help decision makers in construction companies make informed decisions about managing risks in pipeline construction projects. Choosing to use expert systems from all available artificial intelligence techniques is due to the fact that an expert system is more suited to representing a domain's knowledge and the reasoning behind domain-specific decisions. The knowledge-based expert system can capture the knowledge in the form of conditional rules which represent various project scenarios and potential risk mitigation/response actions. The built knowledge in RASPE is utilized through the underlying inference engine that allows the firing of rules relevant to a project scenario into consideration. Paper provides an overview of the knowledge acquisition process and goes about describing the knowledge structure which is divided up into four major modules. The paper shows one module in full detail for illustration purposes and concludes with insightful remarks.

Keywords—Expert System, Knowledge Management, Pipeline Projects, Risk Mismanagement.

I. INTRODUCTION

THIS paper describes a computerized expert system that can help construction companies especially the ones working in pipeline infrastructure projects make informed decisions about risk management in their projects. The research has been tailored to the Egyptian context.

Many pipeline construction projects in the Middle East fail to be completed as per the established targets. A frequently reported failure is substantial project delays [1]. Pipeline infrastructure projects like other types of construction projects have their share of uncertainties and hardships. It is no exaggeration saying that no project is absolutely risk-free [2]. In real industry practice, many project/construction managers in these countries mostly make their decisions based on intuition, judgment, and experience rather than through a formal and systematic risk management process [2], [3].

It can be useful to aid in such process by providing high quality domain knowledge to support decision-making. Expert systems can particularly support decision-making because they contain high-level knowledge about a subject area often called a domain [4]. Expert systems are computer applications

which embody some non-algorithmic expertise for solving certain types of problems [5]. The authors developed a tool

named Risk Advisory Smart System for Pipeline Projects in Egypt (RASPE) which can be utilized as smart advisor to help construction companies take suitable and effective actions prior to project starting to avoid or mitigate the unfavourable consequences of risks. RASPE was developed using Visual Studio.

II. RASPE RISK MANAGEMENT KNOWLEDGE

A. Knowledge Acquisition

Almost everyone agrees that this task is the bottleneck in the expert system construction. Since the expert system relies heavily on knowledge, the quality of the acquired knowledge will often be the contributing factor to its success. Knowledge acquisition can be likened to a distillation process where the essential facts and rules must be isolated from information that contains many impurities. Instead of being embedded in various handbooks and manuals, the knowledge in many domains is available only to experts and is never been written down in a structured form. In such cases, the task of building an expert system must begin by acquiring or capturing the expert knowledge [6].

Generally speaking the knowledge acquisition can be made via manual, semi-automatic or automatic means. RASPE knowledge was acquired manually, as it was rather difficult to find great number of cases to apply the automatic knowledge acquisition approach. Besides, risk response/mitigation actions are a subjective issue. Each expert can consider these actions from his/her own perspective. The manual acquisition gives the experts more flexibility to express his/her knowledge and communicate to the researchers while they capture the knowledge in useable form.

The knowledge acquisition proceeded via two stages as detailed hereinafter.

1. Analysis of Public Domain Knowledge

The public domain knowledge was captured from a variety of published theses and academic references in the area of construction risk management. Also, several international contracts for mega infrastructure projects in Egypt, and which had a foreign party, were reviewed for knowledge worthy of inclusion in the system's knowledge base. The public knowledge was essential to get the first author—who acted as the knowledge engineer in the knowledge acquisition process—familiar with the domain's context and terminology. While capturing the knowledge through the relevant clauses in the examined contracts was not easy to attain, it was very useful to provide broad background about the problem.

2. Extracting the Private Knowledge

The private knowledge was acquired through interviewing domain experts and observing and tracking their reasoning

process. The knowledge related to RASPE is a qualitative knowledge and not a quantitative one. That is why the number of experts was not the problem but rather finding qualified experts to perform that task. Extracting the private knowledge proved to be time consuming however indispensable to forming the knowledge base.

The public and private knowledge revolved around four major scenarios. Accordingly, RASPE was made to include 4 components or modules. For illustration, details of one of these modules will follow in Section III of this paper.

B. Building RASPE

RASPE was built via the Microsoft Visual Studio Dot Net 6.0 programming language. Visual Studio was utilized due to its simplicity in building either the system’s screens or coding the expert system rules. Also it proved more flexible compared to the available expert systems shells. Systems’ screens were designed to gather information of the project case under study from the system user and then provide recommendations according to the built-in knowledge.

III. RASPE STRUCTURE: AN ILLUSTRATIVE MODULE

RASPE knowledge base consists of four modules. For illustrative purposes, one of the 4 modules will be presented in this section. Each module incorporates a number of project risks. For the specific module presented in this section, five project risks are included, four of which belong to the same risk group i.e. financial risks. The risks are lack of owner financial ability, delay of progress payment, in-house cash shortage, and lack of contractor financial ability. Potential for claims development in that same context is further addressed.

A. RASPE Illustrative Module – Part I

The module starts with identifying the stage at which financial risks and corresponding claims are recognized. As noted in Fig. 1, the module branches out into 2 sections; one that addresses the project pre-execution stages i.e. studies and contracting stages while the other addresses the execution till satisfactory fulfillment of contract requirements.

1. 1st Branch: Studies and Contracting Stages

Branch starts with a fundamental advice for pipeline contractors in studies stage. The advice is to examine and take sufficient precautions for the possible lack in financial ability of owner. This is a critical element in the success of construction projects at large and pipeline projects in specific. That advice was concluded after a thorough study of several previous and current pipeline construction project cases.

Understanding and handling issues related to owner’s financial status differs according to the prior experience of contractor with the project owner. So, the expert system module inquiries about whether the contractor has dealt with that same owner in the past in another project or not. There are apparently two possibilities or scenarios.

2. Scenario (1): Contractor Has Dealt with the Same Owner Prior to This Project

In this case, the contractor possesses previous records for that same owner, so contractor can thoroughly examine the records especially the most recent ones to confirm the financial status. If the historical records show the financial history to be rather questionable, some future hardships become a possibility e.g. delays or stoppage of progress payments. It is wise for contractor at this early stage to make a judgment call of whether to enter project or decline the owner’s invitation for bidding.

If the historical records show the financial status to be solid enough, the contractor needs to proceed with examining the specific source(s) and adequacy of funding for the upcoming project. With this being examined, the contractor should then question the relative importance of that project to the owner for further consideration of project suitability.

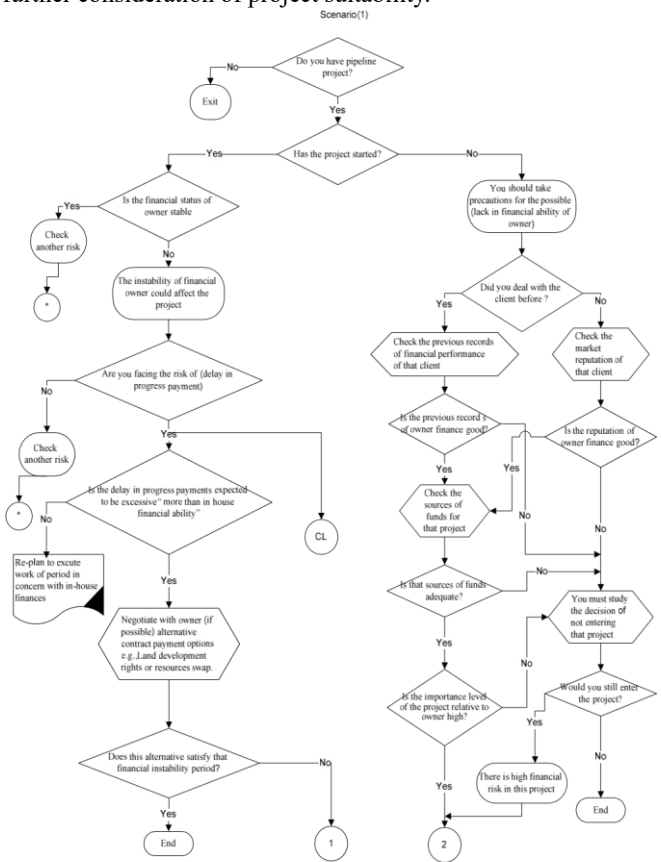


Fig. 1 Module 1 Part I

3. Scenario (2): Contractor Has Not Dealt with the Same Owner Prior to This Project

If the contractor has not been involved in any previous projects by the same owner, it is deemed necessary to check on the market reputation of that owner. If reputation and financial status were highly regarded, contractor can proceed to examine the source(s) and adequacy of funds allocated to the upcoming project as described before. When the financial reputation of the owner is unacceptable, then the contractor should consider abandoning this project venture. If there remain some compelling reasons to enter the project, e.g. governmental pressures, the contractor should expect and prepare for a high financial risk in the upcoming project. Such situation is dealt with in part II below.

4. 2nd Branch: Execution Stage:

This branch considers that the contractor has already won the bid and signed a contract for work execution. The contractor is advised to always keep an eye on the financial stability of the owner. If the owner consistently shows good signs for stable financial status the contractor can then address other types of risks in the project environment. However, if there are warning signs of faltering financial conduct by the owner the contractor should take note and be ready for action.

In case of financial instability of the owner, the contractor could face, or could already be facing, delays in progress payments. Contractor should determine whether these delays are excessive or not. As known, excessive delays in progress payments could put major financial burden on the contractor's in-house monetary stream, which is highly unfavourable. But when delays are not as excessive, then the contractor can cover the period(s) of monetary shortage through in-house financing and/or re-planning of works to be executed in the period in concern and when in-house financing is needed. Meanwhile if the delay in progress payments is excessive, i.e., the contractor cannot cover that period from in-house resources, then contractor should negotiate with owner, if by any means possible, to consider alternative contract payment options, e.g., land development rights or resources swap. If alternatives can sufficiently cover the period of owner's financial instability, then a resolution is in reach. Otherwise, the contractor should proceed to part II.

B. RASPE Illustrative Module – Part II

Similar to part I, part II also recognizes the pre-execution and execution stages of a project, Fig. 2.

1. 1st Branch: Studies and Contracting Stages

This branch commences with an important advice to the contractor; that is taking prior precautions to avoid possible delays in progress payments. There are options to that end, one of which is to negotiate obtaining a credit letter from the owner to cover total price of the project. This credit letter will create an assurance resource for the contractor about future progress payments and will guarantee financial stability for contractor throughout execution.

Owners are not always keen to provide such support to the contractor. If the owner disagrees to providing such credit letter, the contractor should take three pre-emptive actions which are to:

- 1) Explicitly specify the timing of payments in the contract,
- 2) Specify extension or compensation clauses in contract for case of payment delays, and
- 3) Examine previous and on-going projects comparable to the one at hand in order to estimate/assess a sufficient financing risk premium.

2. 2nd Branch: Execution Stage

Own financial status i.e. the contractor's financial status and the risk of in-house cash shortage need to be investigated. If the financial resources are in doubt, the main causes of inhouse cash shortage should be investigated. Investigation should first examine the internal sources of funding then moves to the external ones. With the main causes of in-house cash shortage

detected, one or more of the following mitigation actions could be pursued:

- 1) To seek the owner's approval of replacing the retention money with bank bonds, and
- 2) To re-plan/change the schedule of work to increase income in period of presumptive cash shortage.

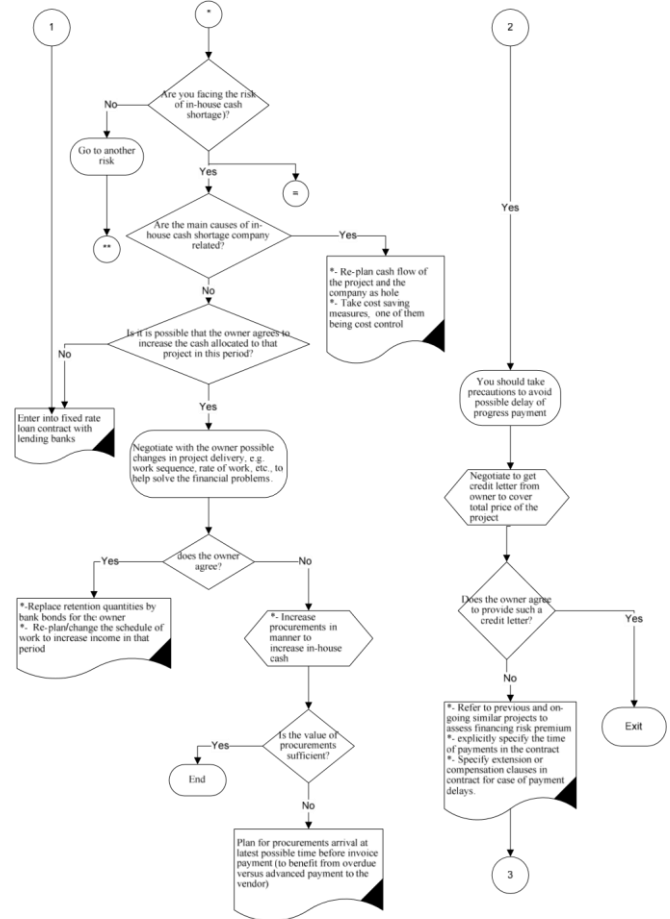


Fig. 2 Module 1 Part II

In case owner disagrees with the actions, the contractor can opt for increasing procurements in a manner that increases cash flow from owner, when contract allows this. If the increased procurements surpass the financing shortage the matter can be considered resolved. If still not sufficient, contractor has to pursue other venues, such as planning for procurements' arrival at the latest possible time before invoicing (to benefit from the overdue versus advanced payment to the vendor).

C. RASPE Illustrative Module – Part III

Similar to parts I and II, part III also recognizes the preexecution and execution stages of a project, Fig. 3.

1. 1st Branch: Studies and Contracting Stages:

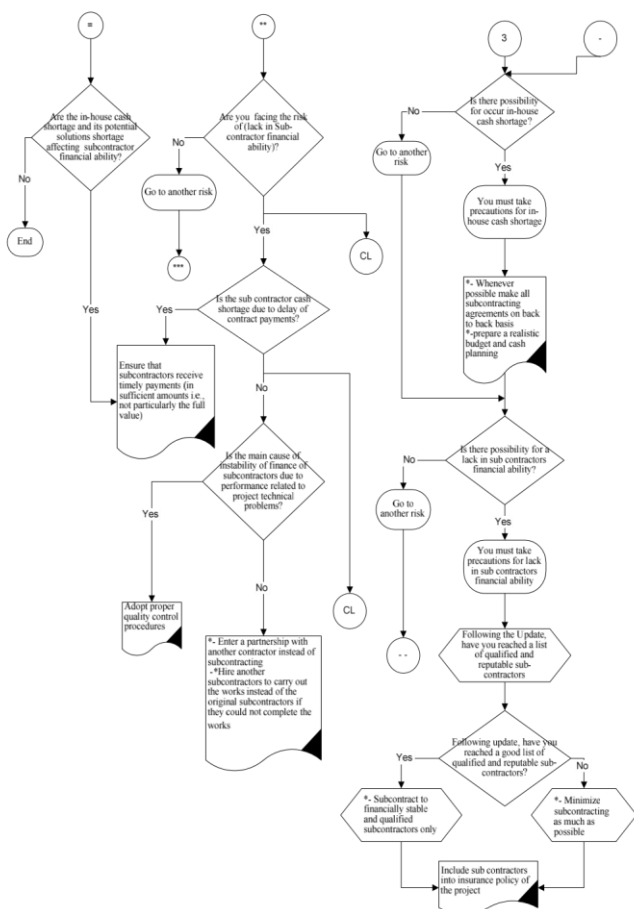
Branch starts by inquiring about the possibility of in-house cash shortage for contractor during project execution. This should be examined prior to the execution stage. If such possibility exists, contractor can opt for the following:

- 1- Make all subcontracting agreements on back-to-back basis whenever possible, and

2- Prepare a realistic budget and cash plan accordingly.

There is, of course, another scenario which is lack of subcontractors' financial capabilities. When this scenario is envisioned by the contractor, more stringent subcontractor selection process should be adopted. It is advised that the contractor keeps at all times a consistently updated list of qualified and reputable subcontractors to cooperate with. When selecting a reliable subcontractor becomes difficult for a certain job, the contractor can try to execute with own workforce whenever possible. Minimizing subcontracting can sometimes become the best mitigation strategy for potential

In all cases, when a subcontractor comes on board, a proper insurance policy that covers the subcontracted work should be



risks in a project.

acquired.

Fig. 3 Module 1 Part III

2. 2nd Branch: Execution Stage:

Contractor needs to continuously monitor the subcontractors' performance. When a subcontractor suffers from cash shortage due to delayed contractor payments, the contractor must then ensure that subcontractors receive timely payments. Payments in sufficient amounts, i.e. not particularly the full amount of invoice, can be sometimes accepted. Meanwhile, if the subcontractors cash shortage is not due to delayed payments by contractor, the root causes of subcontractor's troubles need to be determined, whether due to technical problems in project or otherwise. If the primary cause of troubles is related to project technical problems, then contractor must adopt proper quality control procedures. But, if the primary cause of troubles is related to project technical problems, there are two mitigations actions that can potentially be pursued by the contractor:

- 1- Enter a partnership with another contractor instead of subcontracting, and/or
- 2- Hire other subcontractors to carry out the works instead of the original subcontractors if they fail to complete the works.

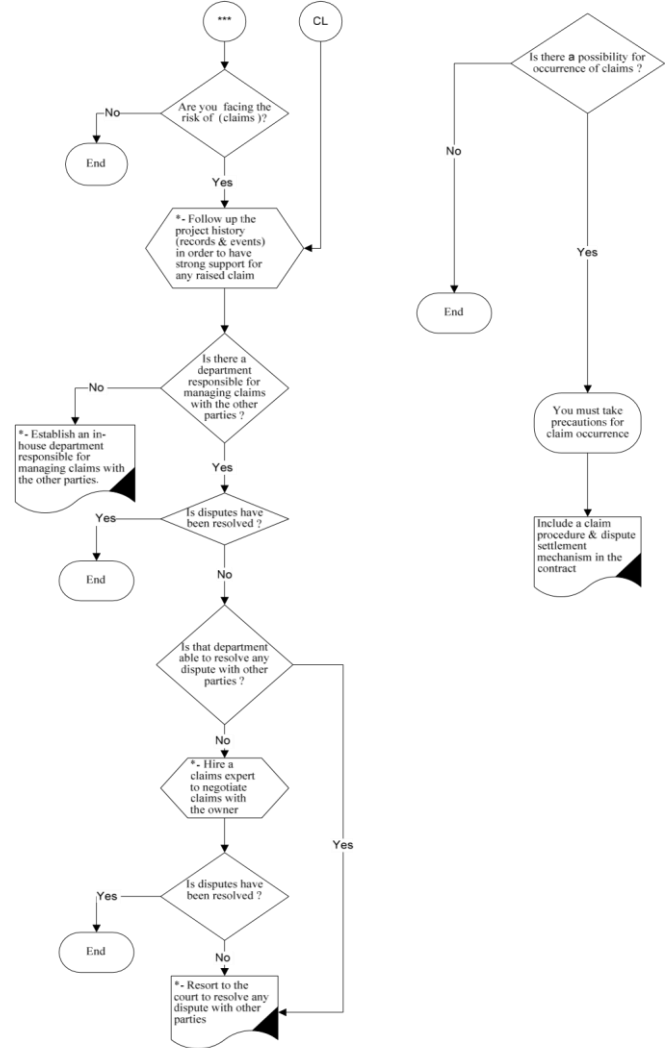


Fig. 4 Module 1 Part IV

D. RASPE Illustrative Module – Part IV

As with the previous parts, part IV also recognizes the preexecution and execution stages of a project, Fig. 4. Both tracks are comparable and thus will be described together. When the possibility of claims risks arises, the contractor should establish a solid system for project monitoring and event recording. Those experienced in claims management know quite well how much difference it makes to have good documentation to support submitted claims.

If contractor does not have in-house department or entity responsible for managing claims with outside parties, then the contractor should consider establishing one. Even if such department exists, an inquiry should be made of whether most claims and disputes handled by this department were resolved in positive way or not. When concluded that the claims department failed on most previous disputes and cannot properly handle potential future claims, the contractor should consider hiring a claims expert to negotiate claims with the owner. In the case of outstanding claims that are not possible to resolve, the contractor can resort to the last option, i.e. the court of law, to resolve any unsolved dispute with other parties.

IV. CONCLUSION

This paper has introduced a practical expert system called RASPE, which can provide industry practitioners with means to better deal project risks/uncertainties. The system was developed to reflect the Egyptian context. So the reader should keep in mind that own practices might differ due to the different legal and contractual systems in place. Also it presented one module of the different modules in the actual system. The presented module addressed the financial risks and relevant risks to this particular type.

RASPE clearly differentiated between the aspects and precautionary actions to address prior to execution i.e. during the studies and contracting stages and those relevant to the execution stage itself. One of the strengths of expert systems is the ability to capture the knowledge in the form of conditional rules. The paper did not present the rules per se but they can easily be extracted from the system flowcharts presented throughout the paper.

While the mechanism can provide a handy advisory tool to help construction companies decide on and pursue suitable risk handling actions, further validation is needed with multiple case studies to confirm efficiency of system and the breadth of knowledge built into it. It is possible that during the validation that further bits of the domain knowledge become apparent and thus worthy of being included in the expert system knowledge base. Such activity may be pursued in the future by the authors.

REFERENCES

- [1] N. Y. Zabel, M. E. Georgy, and M. E. Ibrahim, "Developing a Dynamic Risk Map (DRM) for Pipeline Construction Projects in Middle East", in 8th International Conference on Risk Analysis and Hazard Mitigation, Brebbia, C. (ed.), 175-187, Wessex Institute of Technology, UK 2012.
- [2] M. E. Georgy, N. Y. Zabel, and M. E. Ibrahim, "A balanced risk treatment for construction projects." In 7th International Conference for Structural Engineering and Construction, Honolulu, USA, 2013.
- [3] N. Y. Zabel. "Risk Management of Pipeline Infrastructure Projects in Egypt ", MSc. Thesis, Faculty of Engineering, Cairo University, Giza, Egypt, 2007.
- [4] L. K. Kaetzel, "Highway Concrete (Hwycon) Expert System in the Classroom" in Third Annual Undergraduate Faculty Enhancement Symposium on Teaching the Materials Science, Engineering, and Field Aspects of Concrete, Cincinnati, Illinois, US, 1995.
- [5] D. Merritt, "Building Expert Systems in Prolog," Amazi.inc, 5861 Greentree Road Lebanon, OH 45036 U.S., 2000.
- [6] Y. F. Bazan, "An Expert System For Material Claims Guidance", Doctor of Philosophy Thesis, Structural Engineering Department, The Cairo University In Giza, Egypt, 2001.