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A FRAMEWORK FOR RISK ANALYSIS IN INFRASTRUCTURE PROJECTS

METODA ANALIZY RYZYKA W INWESTYCJACH INFRASTRUKTURALNYCH

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Summary: Due to various uncertainties all capital intensive projects often suffer from risk. Both international as well as Polish infrastructure projects are subject to often excessive risk. One of the main reasons for poor risk estimates in those projects is lack of coherent risk assessment framework. Process of risk assessment could be optimized and could produce much better results if appropriate risk analysis framework is proposed. The aim of this paper is to present the proposal for such risk analysis framework which allows for optimization of risk appraisal in infrastructure investments. Proposal presented in this research is based on analysis of examples of real investment conducted in the European Union. This is further augmented by the results of questionnaire review of construction companies in which they were asked to identify significant (from the contractor perspective) types of risk. The resulting framework proposes layered approach to risk analysis distinguishes between three levels of risk assessment. On the top-level major risks facing project participants are addressed like cost, revenue, delay and quality risks. On the mid-level the component risks which influence major risks are addressed. Finally on the basis level the actual risks which represent common risk events present in infrastructure investments are enumerated. Furthermore the interconnections between identified types of risks are described and their contribution to overall risk is discussed. This three stage approach allows for elastic and at the same time complete tool for risk analysis which helps to optimize risk assessment process.

Keywords: risk analysis, risk in infrastructure, risk framework.

Streszczenie: Inwestycje infrastrukturalne realizowane są w warunkach niepewności i narażone na wiele rodzajów ryzyka. Doświadczenia zarówno międzynarodowe, jak i krajowe wskazują, że projekty inwestycyjne w infrastrukturze bardzo często obarczone są finalnie dużo większym ryzykiem niż pierwotnie planowane. Jedną z ważnych przyczyn utrzymywania się tego stanu rzeczy jest brak adekwatnej metodyki analizy ryzyka w takich projektach. Wprowadzenie ramowej metodologii oceny ryzyka pozwoliłoby na optymalizację tego procesu. Celem tego artykułu jest przedstawienie propozycji takich ram analitycznych umożliwiających obiektywizacje procesu oceny ryzyka w inwestycjach infrastrukturalnych. Propozycja ta opiera się na wynikach badań w zakresie praktyki realizacji projektów infrastrukturalnych zarówno w Unii Europejskiej, jak i w Polsce oraz na wynikach badania kwestionariuszowego przeprowadzonego wśród interesariuszy polskich projektów infrastrukturalnych. Zaproponowane podejście opiera się na idei budowy modelu analizy ryzyka na trzech poziomach. Poziom najwyższy reprezentować powinien główne typy ryzyka pojawiające się w przedsięwzięciach infrastrukturalnych, są to: ryzyko czasu, kosztów, przychodów i jakości. Drugi poziom analizy tworzą te rodzaje ryzyka, które oddziałują na powyższe cztery kategorie nadrzędne i które wymieniane są często jako elementy oceny ryzyka w różnych dokumentach programowych. Wreszcie na poziomie najniższym zidentyfikowane zostały konkretne przejawy ryzyka – a więc kategorie ryzyka tak jak są one postrzegane przez uczestników projektów. Artykuł podejmuje także problem relacji pomiędzy poszczególnymi rodzajami ryzyka, ich współzależności i wpływu na ryzyko nadrzędne. Zaproponowane trzystopniowe ramy analizy ryzyka stanowią narzędzie umożliwiające kompleksowe i elastyczne podejście do analizy ryzyka i pozwalające na obiektywizację oceny ryzyka w projektach infrastrukturalnych.

Słowa kluczowe: analiza ryzyka w projektach infrastrukturalnych, ocena ryzyka inwestycyjnego, ramy analizy ryzyka w projektach infrastrukturalnych.

1. Introduction

Investment projects are subject to many risks. Due to various uncertainties all capital intensive projects often suffer from budget overruns and schedule slippages. The track record of infrastructure investments shows that this is rather a rule than exception. Very often the costs of infrastructure projects are underestimated, the timetables are overly optimistic and projects do not generate sufficient revenues or infrastructure delivered is of poor quality.

This is a case of international projects as proven in cross-country research conducted by Flyvbjerg [Flyvbjerg, Skamris Holm, Buhl 2003]. This study examining 258 infrastructure project shows with overwhelming statistical significance that in terms of costs transport infrastructure projects do not perform as promised. Even as many as nine out of ten projects face risk increases over the acceptable levels. For fixed infrastructure in rail investments the average cost risk increase over planned level is 45%, for fixed links such as tunnels and bridges, the number is 34%, and for roads exceeds 20%.

The investments in Polish infrastructure face the same problems. It has been reported that out of 736 infrastructure road projects in cities conducted in years 2008–2011 only 338 has been finished accordingly to the plan [Najwyższa Izba Kontroli 2011]. Similar situation could be found in infrastructure projects prepared by GDDKiA and PKP PLK. Many of them faced risk increases over accepted levels resulting in cost increases, delays, insufficient revenues generated or poor quality of end product. The reason for this universal failure is lack of sound risk assessment practice. The key component of risk analysis is risk analysis framework which allows for systematic and professional risk evaluation. Practice shows that most investors in infrastructure sector do not use any risk assessment plan nor adheres to any defined risk assessment procedure. To the contrary it is common approach to tackle risk in the *ad hoc* manner without allocating much resources to the process. In many cases risk assessment has been conducted in infrastructure projects only in order to fulfill formal requirement [Borkowski 2011].

The state of the art for project appraisal is frequently used CBA (Cost-Benefit Analysis) methodology advocated mainly by the European Union authorities for assessment of infrastructure. But this methodology addresses risk only in a very broad sense. The failure of many appraisals to capture risk correctly has led to critique mainly from academic perspective [Mackie, Worsley 2013]. But the search for the sources of risk analysis underperformance has been limited primarily to major infrastructure, so called megaprojects [Flyvbjerg, Bruzelius, Rothengatter 2008]. The discussion identifies problem as overly optimistic assessments or strategic misinformation [Cantarelli et al. 2010] but proposals to amend this situation are few. In fact only British government has introduced procedure for dealing with optimism bias which tries to improve risk analysis quality [HM Treasury 2003]. There are other attempts in the field but they suffer from selectiveness and do not offer comprehensive risk analysis frameworks. Interesting examples are Monte-Carlo based quantitative assessment CBA-DK model proposed in Denmark [Salling, Lelur 2011] or US handbook on risk assessment of road projects [Moleenar, Anderson, Schexnayder 2010].

Process of risk assessment could be optimized and could produce much better results if appropriate risk analysis framework is employed. The main mistake in risk appraisals is that stakeholders do not understand nature of risk and are unable to distinguish between different risk types and factors. The risk analysis framework seems to be easy to introduce and easy to use tool which might help to straighten many problems encountered during assessment. The analytical framework proposed in this article could be a useful tool allowing for more comprehensive and cohesive dealing with risk in infrastructure projects.

2. Current risk assessment practice in infrastructure projects

The problem that any infrastructure project manager faces is lack of formal coordinated and well developed risk assessment framework. Although there are many risks mentioned in particular construction projects there is substantial lack of clarity in their definition. Existing standards either omit various types of risk or mix risk sources with risk consequences. The review of current infrastructure projects appraisal methodologies reveals that risk typology developed in them which project managers are supposed to follow is either rudimentary or none at all [IC-E-U 2013]. At the same time the evidence of construction failures shows that there is a need for clear risk analysis framework.

Uncertainties and risks inherently exist in construction projects. The specific condition in which risk analysis is conducted in infrastructure projects results from their specificity. Most of the inherent uncertainties are often unique for particular project and are drawn from variety of sources. In addition projects tend to be long-term endeavors resulting in risks being rather dynamic than static. Furthermore in infrastructure risks are often interrelated with situations when two or more independent risks generate new risk. Finally the sum of independent risks in infrastructure projects tends to be more than risk effects of the components considered separately. For example, if work has to put on hold due to severe weather conditions it may cause delays in other parts of project creating risk for timely delivery, risk for storage of materials, risk of additional employees needed, etc. In addition, external factors can have a very significant effect on this type of projects. For this reason multidimensional risk framework is needed to properly estimate risk in this type of projects. At the same time existing methodologies tend to offer one level and often incomplete risk assessment strategies.

The typical characteristics of infrastructure projects make project management and risk analysis more important than in other development activities. Project success is usually measured by its schedule, costs and revenues, and its quality. Broadly, various risks can affect these basic factors against the success of a project. For large projects number of risks involved which influence those basic outcomes is substantial. Infrastructure investments tend to be very large scale projects committing huge financial and material resources over considerable length of time (the scale of expenditure is depicted in Figure 1).

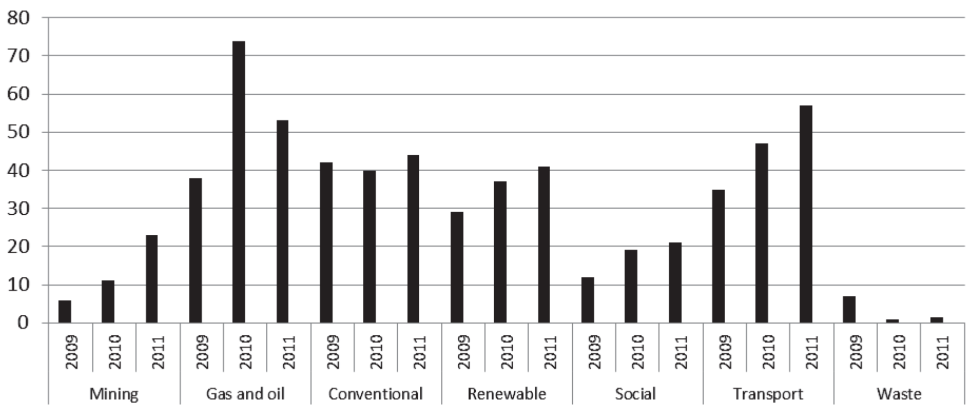

Figure 1. Financing of world infrastructure in billion USD

Source: Infrastructure Journal [http://www.ijonline.com]/, 03.04.2014.

This creates significantly bigger pool of risks, which needs to be considered, than in other development project and points to the fact that many risks need to be addressed. In general, the project scale and complexity have close relation to the schedule of the project; and at the same time those two aspects have relations with the impact or severity of risk. The general rule here is that the larger and more complex the project and the longer the time is required to complete the project, the more severely the project will be affected by risk.

In addition infrastructure investments tend to involve many different stakeholders. Due to the fact that they are often developed in stages some risk types are inherited in new projects from past developments. Many infrastructure upgrades are built on old infrastructure objects thus many risks generated by this frequently old and poor quality items are carried to new projects.

Main policy documents dealing with risk assessment procedures in infrastructure investments do not offer a risk analysis framework which accounts for all those peculiarities [European Commission 2008]. Firstly they do not enumerate risk types for the purpose of preparing risk assessment plan. Secondly they give only general guidance and refer to risk measurement techniques like sensitivity analysis in response to key risk factors or Monte Carlo for numerical risk assessment. Those guides are broad in nature and provide few detailed insights. For instance national appraisal documents based on general EU guidance could differ in many details like [Mackie 2006]:

- investment variants chosen,
- methods for cost calculation,
- inclusion of certain cash flows,
- discount rate applied,
- the way ENPV and IRR of the project is tackled,
- inclusion or not of externalities,
- inclusion of social costs and benefits of the project.

They key role in assessment of transport infrastructure project within EU is given to the CBA (Cost-Benefit Analysis) analysis with supportive role of MCA (Multi Criteria Analysis). The widespread use of those methods implies that analysis is directed more into expected costs and benefits of the investment (in broad socio-economic terms) rather than into actual risk analysis [Florio 2006]. From the risk perspective the main trouble with adoption of this approach is that many factors which influence cost – benefit ratio and are subjected to various risks cannot be easily measured because they are not given in monetary terms. For instance value of time could only be estimated using proxies representing unit costs which are treated equally for all investments, which is obviously simplification. In infrastructure projects there are more of such proxies based on average values (established based on expert opinions) they are used for estimation of value of time, value of life and health, environment and pollution [Florio (ed.) 2007]. Looking into national practices and considering Poland as example with its assessment rule book [Ministerstwo Rozwoju Regionalnego 2007] and Polish version of EU appraisal guidelines [MRR 2008] the following appraisal steps are proposed: 1) project identification, 2) establishment of goals of the investment, 3) feasibility study, 4) financial analysis, 5) socio-economic costs analysis, 6) discounting, 7) economic rate of return, 8) sensitivity and risk analysis. But the section dedicated to risk analysis acknowledges only a need for such an assessment and implies use of sensitivity in regard to factors which could change ENPV of the project by more than 1%. For other risk assessment tools the Monte Carlo method is mentioned as adequate but no insights as to its use are provided. Neither EU level nor national documents discuss the details of risk assessment or provide alternative methodologies. Regardless of the method used for risk assessment the key action on the part of project management is risk identification. For this sound framework dividing and describing different risk categories important in infrastructure projects has to be given. Unfortunately in this dimension guidance documents are mute.

Other supportive documents advised by the Polish Ministry for Regional Development point at risk categories like: construction related risk, accessibility risk, investment preparation risk, demand risk, political risk, macroeconomic risk, regulatory risk, revenue risk, acts of God risk, environmental risk, localization risk and transfer of assets risk [Korbus (ed.) 2010]. These risk types are certainly present in infrastructure projects, yet the list is not complete. But what is more important, there is no clear distinction between major and secondary risk types, thus relations between different risks and their sources are poorly identified. This example is typical for existing national risk methodologies.[1] The proposed risk typologies are lacking in quality as they do not address important risk factors or mix different risk types together.

3. Risk analysis framework

Controversies present in current appraisal methodologies necessitate the proposal for more useful and internally sound framework for risk assessment. This could be done on the assumption that it is not fully possible to measure risk in any infrastructure project as one overall number. Due to the nature of risk and the way risk impacts infrastructure projects it is much better to formulate four major (top level) risk categories and only then analyse risks which have decisive impact on overall risk within each of those major categories.

The framework for risk analysis should be built in three steps: top level risks, mid-level risks and basic risks. This should start with the definition of top-level risk categories. While defining those one should ask the question of what are the most frequent and most severe problems with infrastructure projects? Those are in order of importance: cost escalation during construction, delays in timely delivery of projects, poor quality of what is delivered, and insufficient revenues. The first two are related to the construction phase of the project. The third has its sources in the same phase but manifests itself later – in operational phase, when infrastructure is being used. The last one is significant for projects which are expected to rise revenues and results from insufficient demand. Four types of major risk categories corresponding to those common failures should be considered:

[1] For detailed discussion on various national methodologies see [Borkowski 2013, ch. 5].

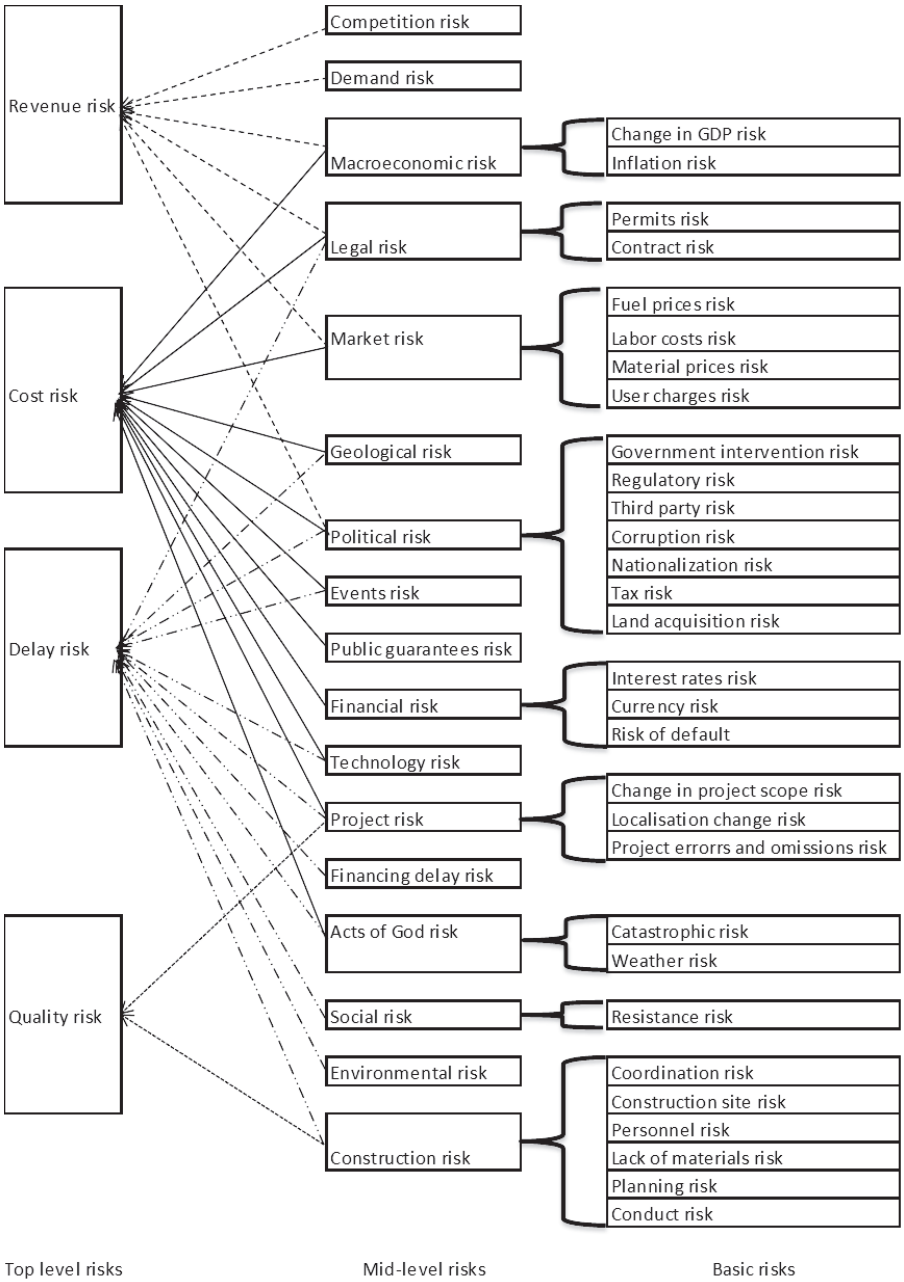

Figure 2. Model for risk assessment framework in infrastructure projects

Source: own elaboration.

- cost risk (risk that cost of the project will increase beyond planned),
- delay risk (risk that project will be completed later than planned),
- quality risk (risk that quality will not be adequate),
- revenue risk (risk that revenues generated by project will be less than planned).

Top level risks are those which have to be considered separately and which at the same time have decisive impact on project success or failure. From the infrastructure investment perspective these are the risks which correspond to the problems of:

- Will the project work (quality risk)?
- Will the project be completed on time (delay risk)?
- Will the project be completed within allocated budget (cost risk)?
- Will the project generate sufficient revenue (revenue risk)?

The framework for risk assessment should link all important risk categories which are commonly used in risk assessment and identification with the above four top-level risk categories. The proposal describing this relation is given in Figure 2.

This proposal for risk division is consistent with project phasing as observed in practice and discussed in project delivery guides like for instance UNIDO feasibility guidelines [UNIDO 1996]. In the pre-investment phase the most important are risks which could distort optimal planning. In this phase the final timetable for infrastructure construction is set and costs are calculated. Therefore risk of delay and risk of costs apply to this phase. At the same time those risks are influenced by events which occur during construction phase. Risk of quality and risk of revenues are delayed in time, they occur only in the operational phase. Therefore they are separated from two previous risks. Certainly there might be a link created between risk of cost or delay and risk of quality in the sense that the latter results from the former. Yet it is more appropriate to look into underlying causes which could be similar or not for both groups of risks. Thus it is necessary to distinguish second level risks which group events responsible for the top-level risks. On that middle level the following risk categories could be identified: competition risk, demand risk, microeconomic risk, legal risk, market risk, geological risks, political risk, acts of God risk, events risk, financial risk and risk of public guarantees, technology risk and project risk, risk of delays in financing, environmental risk and social risk, and finally construction risk.

The risks identified at the middle level are commonly found in project management guides (although often not all of them or wrongly bundled together), instructions for assessment of construction projects, instructions for various control bodies (environmental, design, engineering control) or are formulated by authorities. They represent the most commonly addressed issues in project development and accompany various practical tasks within the projects. One other important observation is that some of those risk groups could influence more than one of the top-level risk categories due to their multidimensional role in projects.

Introduction of those categories has ordering and systematic character. Yet attempts to use them in practice might lead to confusion. They are still highly theoretical and do not deal with risk on the lowest level – level of particular adverse events which are described as risks and which are characteristic for particular project. This leads to the need to move to the third – lowest level in developing risk analysis framework.

On the lowest level – which is the level of risk perception by actual participants in the project (managers, financiers, construction workers and organizers, etc.) particular risk events are identified. The occurrence of particular adverse situation is usually the cause for the definition of a particular risk. Those individual risks faced by individual people involved could go in hundreds. And yet there are still certain very similar events which could be grouped as they happen more frequently. This grouping into lowest level risk units will create basis for project risk analysis.

On this level certain mid-level risks could be explained by risk element (lower level risks). For instance the risk of construction could be attributed to the risk of planning, poor realization of project, lack of materials, lack of skilled workforce represented by personnel risk, poor coordination of actions, or risk of unpreparedness of construction site. Similarly project risk could be attributed to risk of project changes during realization, errors and omissions in original project or wrong localization of infrastructure objects. Act of God risk could be effect of either catastrophic events or just less severe changes in weather. In the latter case the term "weather risk" might be coined. Financial risk could be subdivided into currency risk, interest rates risk, credit risk. In financial markets financial risk is subdivided by finance industry and regulators into even more subcategories, however, in construction projects only selected sub-risks are of real importance. One of the most prolific categories is political risk which could result from corruption risk, third party risk, risk of government intervention, regulatory risk, tax changes risk, nationalization risk or risk in land acquisition process. Some of the above categories are universal for every political risk analysis but some (land acquisition risk for instance) are special categories which are important only in infrastructure projects and should be skipped for other types of projects. This once again shows the need for specific defined framework for risk analysis in infrastructure investments. Although of course some global level risks are considered – for instance macroeconomic risk is divided into inflation risk and change in GDP risk, which are common categories for all types of projects, the substantial part of risks associated with infrastructure investments are specific and relevant only to this type of projects.

Specific for infrastructure are divisions of market risk which address only items important from the infrastructure development point of view like: risk of fuel prices change, risk of construction material prices change, risk of labor force compensation change and risk of change in user charges.

Similarity legal risk should be considered under the specific objective of infrastructure development. Therefore, although it is multifaceted risk, only two aspects are really crucial here: risk of non-acquisition of permits and legal risk to contract finalization resulting from mistakes in contractual arrangements.

4. Interrelation between risks in infrastructure projects

The four top-level risk categories are independent but mid- and basic-level categories are often intermingled and influence more than one top-level category. These interrelations are important because if they are not properly understood there is a danger of double counting of some effects.

Revenue risk is determined by lower than planned cash flows from infrastructure use. The major components influencing this category are: competition risk, demand risk resulting from reduced spending on transport by transport users, price risk resulting from reduction of charges either due to the administrative decision, legal constraint or forced by market developments, political risk, legal risk, and macroeconomic risk.

Quality risk results from the mistakes made during construction phase or errors inherent in technical projects. It could be attributed to two major mid-level risk groups: construction risk and project risk. Both of them are subdivided into further lower level categories, yet not all of those subcategories impact quality risk. This depicts broader rule which needs to be taken into consideration while building risk analysis framework – that not all risk elements present on the lowest level are influencing all top level risk categories. To the contrary, within basic risks some will influence one top level risk while others another top level risk. At the same time they all constitute elements of mid-level risk. This is a result of multidimensional nature of risk in complex infrastructure projects where some of them cannot be simply aggregated or disaggregated into fully separate units and need to be analysed in conjunction with other risk types. For this reason while assessing any project, thorough understanding of the nature of the project and its associated risks is needed. For the same reason the building blocks approach should be advocated. For each particular infrastructure project the tailored risk analytical solution derived from this broad framework should be created. In other words the proposed framework shows the maximum risks but for each case should be reduced to the risks actually present in particular project. Those risk units – "risk blocks" in proposed broad framework, are elastic and could be moved in order to fit into particular project specifics. It is one of the major mistakes made by project evaluators that they try to use risk categorization developed for specific project for all projects they encounter. This kind of approach is credible within finance industry in banking sector whereas risks faced by all institutions are very similar [Borkowski 2008]. But in the non-financial sector risks are much more individual. While analysing risk faced by two financial companies one will find them mostly similar while doing this for two non-financial entities will reveal more differences. Thus proposed elastic "building block" usage of the risk analysis framework seems to be appropriate for real sector projects – like infrastructure.

While quality and revenue risks are important for working projects they do not influence decisions as to the construction of infrastructure simply because they apply to the finished projects. For this the analysis of delay and cost risks to which any project is subjected during construction phase is needed.

For the delay risk the major risk components are: environmental risk, project risk, construction risk, technology risk, acts of God risk, events risk, geological risk, political risk, legal and financing delay risks. Once again those mid-level risks could be further divided into specific risks and like in previous cases it needs to be stressed that not all lower level risks constituting mid-level risk categories have impact on those top level risks. The delay risk will result from non-fulfilment of certain project tasks or delay in project delivery set forth in the project timetable. This risk could be limited to delays in particular stages of the project (while whole project delivery is not endangered) or could apply to the project as a whole. There is also interesting interconnection between delay and cost risk. The effects of delay risk could contribute to the increase of cost risk. This is dependent on contract type. If particular contract sets fines for untimely delivery than delay risk has direct impact on cost risk. Another instance when this risk impacts cost risk is when there are certain dates at which credits taken for the project realization have to be paid off and due to the delay it cannot be done. There is then certain distortion in cash flows between project participants resulting in some of them being in default.

The most important part of project risk is cost risk. This is the most common in practice and most dangerous of all major risk categories. It results in direct increase of project costs forcing project founders to look for additional capital. This risk category could be attributed to the certain mid-level risk groups like: financial risk, project risk, market risk, technology risk, Acts of God risk, events risk, geological risk and legal risk. For assessment of cost risk the important question is whether appraisal is being made from the individual (private capital) investor point of view or from the society perspective. In the former case only direct costs incurred by investor matter, in the latter also social costs associated with the project need to be considered. This has strong impact on the treatment of mid-level risks. For instance in case of environmental risk if individual perspective is applied, only eventual fines for environmental damages caused by the project which are levied on the investor should be included in risk calculation. If society perspective is adapted, then permanent damage to environment (treated as reduction of overall resources disposable to all people) needs to be calculated. There are therefore two risk perspectives: that of individual investor (considering only risks impacting his performance) or broader society performance dealing with risks to society. In infrastructure projects the latter approach is usually adopted. In this case additional mid-level risk categories should also be considered. For instance it is then important to include macroeconomic risk defined as the impact that economic environment (terms of trade, investment climate, etc.) has on the project. Another risk group which has to be factored in is social risk – understood as effect of reduced life quality for people living close to the newly build infrastructure. Those types of risk are of course very difficult to assess and monetise and are often subject to different approximations. Then there might also be a need to include risk of public guarantees in case the government guarantees private developers of infrastructure either certain level of costs or participates in credit financing. This guarantee if exercised will ultimately become burden to country budget.

Mid-level risks are result of actual risk events occurring during project realization. From the proposed list of significant basic risks those having the highest impact on cost risk category might be pointed out based on practical project analysis [Borkowski 2013, pp. 292–294]:

- mistakes in project design,
- poor coordination,
- change in project scope,
- weather,
- political decisions,
- delays or lack of payments.

Those major risks are consistent with the study conducted among the project participants in Poland. The study has been based on the questionnaire enumerating basic risk types. Participants – representatives of the construction companies involved in the infrastructure projects in Poland – have been asked to evaluate risks on the scale from 0 to 5. Two highest scoring risks in this evaluation were delays or lack of payment, changes in project scope and mistakes in project design [Borkowski 2013, pp. 315–318].

5. Conclusions

The proposed framework for the analysis of risk in infrastructure investment projects might be treated as a reference scenario for the risk assessment procedure in this type of projects. Due to its three-layer construction it allows for flexibility necessary in analysis of often different in scope investments at the same time providing systematic tool which addresses all major risk types encountered in infrastructure projects.

The framework could be used for any infrastructure project assessment but has been checked in practice through consultation with stakeholders for the specific sector of transport infrastructure project. This test provides insights as to which risk categories should be treated as most important and how to make internal subdivisions between often multilayered risks to avoid double counting. This could be achieved by distinguishing between four major risk categories and resignation from treatment of risk as one final number. The four major risks categories in infrastructure projects are risk of: quality, revenue, delay, and costs. Those should be treated separately as they are not compatible in both causes and unit of measurement. The common risk factors (underlying risks) for some of them could be however identified and this could be done by distinguishing between risk components of middle level which represent most often used risk categories. Yet what really cause risk in projects are actual risk events, thus proposal to further disaggregate risk into basic risk-cause units. This is done by proposing list of basic risks present in infrastructure projects. The proposal is based on two sources – comprehensive review of investment projects in infrastructure both in Poland (more than 360 projects were considered) and abroad as well as questionnaire analysis of project stakeholders. The test conducted for transport infrastructure sector allows for establishing basic risks influencing project overall top-risks. It is striking that among most significant risks in infrastructure are those connected to actual construction process (project risk, construction risk, design risk) and seldom those associated with financial factors (currency risk, interest rates risk). Thus another conclusion could be made – infrastructure projects differ significantly from the projects in financial sphere. Therefore risk procedures prepared for financial industry (or specifically banking sector) cannot be applied for non-financial risk appraisals. Separate frameworks tailored to the needs of non-financial uses like the one proposed in this paper have to be employed instead.

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