Risk-bearing capacity testing of and within PPP projects

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Abstract
The concept of risk-bearing capacity testing will be adapted to PPP projects and the PPP players. This allows for transparency and an in-depth analysis of the project’s risk situation. The contractual PPP risk allocation will be rationalized and thus enhanced.

Keywords: Public private partnership, risk allocation, risk-bearing capacity

Introduction
Many national economies are confronted with infrastructure investment needs. To meet these needs, Public Private Partnership (PPP) has become an alternative to traditional public procurement. One decision-making problem of high importance for PPP projects is the derivation of the optimal risk allocation (RA) for the PPP contract. Andersen and Enterprise LSE (2000), Delmon (2009) as well as Girmscheid (2013) state that RA for PPP projects takes place mainly in a qualitative way according to intuitive, habitual or opportunistic criteria, or bargaining strength. The complexity and long-term character of a PPP project, however, could well benefit from rational decision-making. This paper presents research results to rationalize the RA for PPP contracts.

Status Quo
A thorough analysis regarding state of practice and state of research in Switzerland, Germany, the United Kingdom and in international institutions reveals that the RA process generally lacks standardization and adherence to clear and traceable decision criteria. On the one hand, basic principles like maximization of value for money were developed in practice. Their actual applicability to unique projects, however, stays unclear because detailed solutions are not provided. On the other hand, the research community has been dealing with various problems on a very detailed level, but without setting the solutions in a context. Again, the actual applicability stays unclear.

Based on the research gap described above, Girmscheid (2013) developed the concept of a rational RA model for PPP projects. Besides proposing clear RA criteria, Girmscheid (2013) in particular developed a concept for risk-bearing capacity testing of PPP projects, based on the following hypothesis: A risk allocation can only be rational if the risk coverage masses of the private consortium are big enough to cover the risk load resulting from the risk transfer.

The necessary core modules of a holistic rational PPP risk allocation model can be derived from the hypothesis above: (1) rational RA concept, (2) risk load derivation, (3) risk coverage
mass derivation, and (4) risk-bearing capacity test. In a preliminary step, the model considers the rational information acquisition for model application according to the typical risk management steps (Firmenich and Girmscheid 2013a). The model’s modules and their relations are displayed in Figure 1. Firmenich (2013) presents how an initial risk allocation as precondition for risk load derivation can be determined according to a set of clear, traceable and transparent criteria that are easily applicable in practice. Firmenich and Girmscheid (2013b) demonstrated how the risk load derivation can be done using a Monte-Carlo-Simulation (MCS). In particular, this concept allows the simulation of a time specific risk load profile of the private consortium in total and its members.

Figure 1: Concept of a rational risk allocation and risk-bearing capacity model for PPP projects

**Implications**
This paper contributes to the development of a holistic risk allocation model with rational, traceable and transparent criteria on a detailed level. It aims at considering all steps of a rational risk management with focus on risk allocation and risk-bearing capacity testing. The model is embedded in a context that allows for applicability in practice. This paper presents, firstly, how the risk coverage masses of the private parties can be derived from the cash flow model and, secondly, how risk load and risk coverage masses can be opposed for a time-specific risk-bearing capacity testing.
Research Methodology

The paper deals with the rationalization of decision-making. The need for a rational risk allocation model with risk-bearing capacity testing was derived from an according comparison of state of practice and state of research regarding PPP risk allocation. This comparison showed that detailed specific causalities and processes according to clear criteria for project specific risk allocation and risk-bearing capacity testing embedded in a holistic and applicable frame were not available yet. Research results developed are assessed regarding viability, validity and reliability. Viability and reliability are supported with an application test. The three-stage theoretical framework ensures validity:

(1) Model structuring and differentiation according to cybernetic systems theory: Cybernetic systems theory is based on general systems theory according to Bertalanffy (1969). A system can be described as functional, structural and hierarchical concept. Figure 1 integrates all three system dimensions applied to the research problem of rational RA.

(2) Theoretical embedment of the problem: The interpretation, explanation and design of the socio-economic environment in relation to the relevant research can be supported by grounding the work in established theories. In particular, this approach reduces the unavoidable subjectivity of the researcher. New Institutional Economics (NIE) is chosen for the given problem. All three elements of NIE, Property-Rights-Theory, Transaction Costs Theory, and Principal-Agent-Theory are considered as relevant.

(3) Methodical realization of objectives: Finally, the methods are chosen to achieve the research objectives in the given context. Due to the aimed for rationalization, focus is laid on quantitative, probabilistic, and logical methodologies.

The discipline of construction management takes a special role insofar as it lies in the intersection between sociological, economic and technical sciences according to Girmscheid (2007a). Consequently, this research does not only require but demands an interdisciplinary mindset. The transfer of theories, methods and concepts from one discipline of research to another is thus self-evident and is the leading methodical principal of the presented work. In this case attention is given to applicability of theoretical and empirical economic and social sciences to practical problems of construction management.

PPP risk-bearing scenarios

Basic information

Schierenbeck and Lister (2001), p. 362 were the first to formulate two principles of risk-bearing calculus for business entities in the finance industry:

- The prudently calculated risk load potential should not exceed defined risk-bearing potential (according to representative risk load scenarios);
- Losses and/or liquidity deficits because of actual risk occurrences are to be limited consequently according to a coordination system of risk limits.

The latter is particularly relevant if the risk-bearing capacity needs to be ensured over various levels of a business entity (originally for financial institutions). This is also relevant for PPP projects due to the hierarchic consortium structure. On a first risk transfer level, risks are transferred from the public client to the Special Purpose Vehicle (SPV) as representative of the
consortium. On a second risk transfer level, risks are transferred from the SPV to the consortium members, in particular to the contractor and the operator. This risk transfer is usually conducted with a back-to-back contractual arrangement. However, if the risk recipient fails completely, the responsibilities will fall back to the original risk sender. This is the main reason why it is in the interest of the risk sender not to transfer more risks than the risk recipient can cover and thus to ensure risk-bearing capacity. Those relations are visualized in Figure 2.

The basic risk-bearing inequality according to Schierenbeck and Lister (2001) is:

\[ \text{Probability (total loss potential} \leq \text{available risk coverage masses)} \geq x \% \]

Schierenbeck and Lister (2001) speak of qualitative risk load scenarios that are “very high”, “average to low”, and “very low” instead of quantitative probabilities. They make very specific proposals for the risk coverage masses, however:
- Surplus profit for the normal risk load case (very high probability)
- Surplus profit + hidden reserves + minimal profit for the negative risk load case (average to low probability)
- Surplus profit + hidden reserves + minimal profit + equity for the maximal risk load case (very low probability)

Figure 2: PPP risk transfer levels

Kremers (2002) adapted the risk bearing calculus from financial institutions to industry enterprises. He differentiates between an earnings perspective (avoidance of debt overload) and a liquidity (avoidance of insolvency) perspective of risk-bearing capacity. He states that risk-
bearing needs to be ensured at every point of time. He proposes as well risk load cases and risk coverage masses that fulfill the risk-bearing calculus respectively. Value-at-Risk becomes the measurement tool of probability for the risk load cases. He differentiates between a normal (N), a stress (S) and a crash (C) risk-bearing scenarios. Girmscheid (2007b) and Girmscheid and Busch (2008) adapt these principles to project-oriented construction enterprises. Girmscheid (2013) adapted the risk-bearing calculus to PPP projects. This paper presents an intensified analysis of how to apply the risk-bearing calculus to a private PPP consortium under consideration of relations within the consortium. In particular, the focus lies on cash flow surpluses, liquidity reserves and equity as risk coverage masses.

### Risk load cases

After risk identification and risk allocation the risk load can be simulated with a Monte Carlo Simulation that uses probability of occurrence, impact, number of occurrence, and time of occurrence as random variables. The results are probabilistic, time-specific, and actor-specific risk load profiles. The application of Value-at-Risk with normal, stress and crash confidence levels $\alpha$ allows the derivation of the risk load cases to be opposed to the risk coverage masses (Firmenich and Girmscheid 2013b).

\[
RC_{t,\Theta}^{\phi}(\alpha_{\Theta}^{\phi}) = F_{t}^{-1}(\alpha_{\Theta}^{\phi})
\]

- $RC_{t,\Theta}^{\phi}(\alpha_{\Theta}^{\phi})$ **Risk cost in the sense of risk load**
- at a certain point of time $t \in [t_0, t_{end}]$
- for a certain risk-bearing scenario $\Theta \in \{N, S, C\}$
- for a certain player $\Phi \in \{\text{total, SPV, construction, operation}\}$

- $\alpha_{\Theta}^{\phi}$ **Confidence level**

- $F_{t}^{-1}(\alpha_{\Theta}^{\phi})$ **Inverse distribution function of random variable impact** $I_{t}^{\phi}$

- $I_{t}^{\phi}$ **Project risk load**

  - $= \text{simulated project risk load (random variable impact)}$
  - under consideration of multiple and time specific risk occurrences as well as the risk allocation

### Risk coverage masses

The risk coverage masses are derived from the plan cash flow model of the project. The masses are prioritized in classes. 1st class risk coverage masses will be used first for any risk load occurring, and 3rd class masses last. The liquidity reserves of the SPV are the project’s net cash available in every period. This is cash-in (borrowed capital during construction and availability fee during operation) minus cash-out (all operative and financing costs as well as reserve building for replacement). The risk coverage masses of the SPV are (1st) the cash flow surplus for equity interest payment, (2nd) a liquidity reserve that is build up from parts of the cash flow surplus for equity interest payment, and (3rd) the cash flow surplus for equity repayment. The operative players (construction and operation) usually do not bring in equity in PPP project. Their risk coverage masses are (1st) the periodic cash flow surplus, (2nd) a liquidity reserve that is build up from parts of the cash flow surplus, and (3rd) a liability limitation (limited loss). If all available risk masses of the operative players are used by an occurring risk load, it is assumed
that the uncovered risk loads fall back to the risk sender, the SPV. If all available risk masses from the SPV (equity) are used, then the debt repayment is threatened. Comparable to the cash flow waterfall that determines the hierarchy of deterministic payments, there is a risk coverage cascade that determines the hierarchy and responsibilities in case of uncovered risk loads.

Ensuring risk-bearing capacity
The risk load classes and the risk load masses are brought together to form the risk-bearing scenarios (see Figure 3). Obviously, the risk load masses need to accelerate with the confidence level applied to derive the risk load classes. The inequalities based on the risk-bearing calculus need to hold for a sound risk transfer. A sound risk transfer in this sense means that the risk load resulting from the risk transfer is covered by the fees paid by risk sender to the risk recipient with a certain probability \( \alpha \). This applies as well for equity brought in by sponsors. This equity will be used during construction and needs to be repaid from the availability fees that create the net cash of the SPV if fees exceed the costs. If the inequalities are not satisfied, there are three options for action:

1. Reducing the risk load by
   a. reducing the risk transfer
   b. applying further risk mitigation measures
   c. adapting the plan scenario
2. Increasing the risk coverage masses by
   a. increasing the cash flow surplus / profits (availability fee ↑)
   b. increasing the equity (availability fee ↑)
   c. increasing the liability limitations
   d. optimizing the plan cash flow
3. Deriving and accepting the confidence levels resulting from fixed risk load cases and risk coverage masses

<table>
<thead>
<tr>
<th>Normal risk load case</th>
<th>( \alpha N \text{ e.g. 0.5} )</th>
<th>1st class risk coverage masses</th>
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<th>Stress risk load case</th>
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<th>1st + 2nd class risk coverage masses</th>
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<tr>
<th>Crash risk load case</th>
<th>( \alpha C \text{ e.g. 0.9} )</th>
<th>1st + 2nd + 3rd class risk coverage masses</th>
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Figure 3: Risk-bearing scenarios

Quality check with applicability test
The concepts described above were applied to a fictive, but plausible PPP building project. The data set was developed with the industry. The project is a newly constructed and operated school. The private consortium covers design, construction, financing and operation. The construction period is planned to be two years and the operation phase is planned to be 28 years. The concept
of project finance is used with an equity share of 10%. A detailed cash flow model was built to derive the risk coverage masses and to simulate the risk load in relation with this plan cash flow model. In the following, the visual analysis of the operator’s stress and crash risk-bearing scenario to ensure risk-bearing capacity regarding liquidity will be demonstrated (see Figure 4 and Figure 5).

![Stress risk bearing scenario operation phase/operator (αS = 0.75)](image_url)

Figure 4: Stress risk-bearing scenario liquidity operation phase/operator (αS = 0.75)

Figure 4 shows a simulated stress risk load of the operator in the operation phase being zero for eleven years. From year three to year eleven the operator’s cash flow surplus is undisturbed by risk occurrences with a probability of αS = 0.75. This allows the build-up of a liquidity reserve from a share of the periodical cash flow surplus. In year twelve and from year 15 on, the stress risk load is greater than zero. The peaks can be related to replacements planned. There is a high risk that these replacements occur earlier or are more expensive than expected. The risk load in the last third of the contract period can be explained with increased uncertainty. Till year 19, the stress risk load can be covered from the cash flow surplus only. However, the build-up of the liquidity reserve slightly slows down. The highest risk load can be observed in year 20 and 21. This is due to an earlier and more expensive replacement, planned originally for year 22. This unforeseen liquidity need consumes the cash flow surplus in year 20 and 21 completely. The liquidity reserve is consumed in year 20 mostly and in year 21 completely. As some stress risk load remains uncovered in year 21, a liquidity deficit arises. Due to the originally planned replacement, year 22 shows a high cash flow surplus untouched by risk impact. Therefore, the risk impact before can be compensated partly by credits on the future cash flow expected. The effect of the consumed liquidity reserves becomes visible in the remaining years. Future risk
impacts are likely because of the uncertainty rising with longer periods under observation. If the liquidity reserve is consumed at one point and if it cannot be built-up again because the cash flow surpluses are needed to compensate for risk loads, then the situation in the last years becomes critical. Plan deviations are more likely in the end due to uncertainty and liquidity reserves are consumed. Therefore liquidity deficits occur if the risk loads occurring at the end cannot be covered by the planned cash flow surpluses.

Figure 5 shows the same concept for the crash risk-bearing scenario of the operator. The liquidity reserve is never built-up because cash flow surpluses are always consumed completely by the crash risk load (exception: year 19). From year four on the operator encounters losses. These losses are calculated against the liability limitation. The liability limit is reached 21. The liquidity deficits occurring from year 21 on for the operator need to be covered by the SPV as the original risk sender (see Figure 6).

Other possible risk-bearing scenarios for other PPP players can be analyzed according to the same pattern. Possible measures against deficits and their consequences could be tested with this tool as well.

Figure 5: Crash risk-bearing scenario liquidity operation phase/operator (\(\alpha_C = 0.9\))
Conclusion

The risk allocation should be determined as rational as possible for the benefit of all parties involved. In any case, the risk transfer proposed should be tested against a side condition to ensure long-term project success: the risk load resulting from the risk transferred with a certain probability should be covered with according financial reserves resulting from the fee paid by the risk sender to the risk recipient. This way risk-bearing capacity is ensured.

If the risk coverage is too low, risk transfer needs to be reduced or fees need to be increased. If the risk coverage is too high, more risks can be transferred or the fees can be reduced. Under consideration of these causalities, the risk-bearing capacity testing does not only ensure a sound risk allocation but creates a traceable relation between risk transfer and risk premium. The holistic approach as presented in Figure 1 allows a project and player specific tailoring of the presented model.

The applicability test shows the importance of a liquidity reserve. If early risk occurrences consume the liquidity reserve and it cannot be built-up again, it is likely that deficits occur at the end of the contract period, where uncertainty is highest and borrowing on future cash flows becomes limited. Another implication from the applicability test is the importance of replacement planning. In particular, the time variance of planned replacements can lead to serious liquidity problems. These consequences for the cash flow might be considered in the replacement planning as risk mitigation measure. Finally, the consideration of consolidation effects within the consortium when dealing with crash risk loads demonstrates that successful PPPs are designed with a common destiny. Every player should have an interest in the success or
at least the limited loss of the other players. This way, every player will actively participate in the partnership.

Of course, the tool presented is only as strong as the input stemming from risk identification and risk assessment. So far, the RA and risk-bearing capacity model has only been tested with one set of project data. Further testing would be preferable, but depends on the availability of further project information. The biggest challenge of the model application will be to find the time during the tight tender process to do this extensive analysis that requires input from all participants. Other fields of application for this due diligence tool might be the reselling of PPP projects during the operation phase or the insurance market. The concepts presented were developed for PPP building projects. An adaption to infrastructure PPP and other to life-cycle oriented projects seems possible and should be tested.

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