# Paradox of the Bermuda Triangle
# Applying Systems Engineering in a PPP-environment

Robert Audsley
Booz Allen Hamilton
7 Savoy Court; Strand
London WC2R 0EZ; UK
audsley_robert@bah.com

René van der Vooren
Movares
PO Box 2855
3500 GW Utrecht; NL
rene.vd.vooren@movares.nl

Erik Elich
Monto
Krommeweg 8
5708 JM Helmond; NL
e.elich@monto.com



**Abstract.** Applying Systems Engineering to a Public Private Partnership (PPP) contract requires a closed-loop control between the project goals, the project management and the content itself. Unexpected events, contradicting incentives and many more reasons can easily open the closed-loop without initially being perceived. All parties involved should participate actively at peer levels in order to assure the closed-loop control. The transparent and phased approach of Systems Engineering supports achieving this peer level closed-loop control.

## Introduction

**HSL-Zuid.** In the Netherlands the High-Speed Line Zuid (HSL-Zuid) connects the country to the Trans-European Network of High-Speed Lines. Fast trains, with a maximum speed of 300 kilometres per hour, will take travellers directly from Amsterdam to Schiphol, Rotterdam, Antwerp, Brussels and Paris. This offers significant advantages.

Travelling by high-speed train is fast and comfortable. Both domestic and international travel times are reduced significantly: thirty minutes from Amsterdam to Rotterdam and 3 hours from Amsterdam to Paris (compared with current times as shown in figure 1). Passengers travel from one city centre to the next, without parking problems, check-in times or changing trains. In this way, travel within the Randstad and to various European cities will become much easier.

**Environment.** The HSL-Zuid offers an environmentally friendly alternative compared to road and air traffic. Figures from the Dutch Nature and Environment Foundation indicate that by 2010 the average aeroplane traveller will cause ten times as much pollution as someone travelling by high-speed train. Moreover, the HSL-Zuid has long-term sustainability: the railway line is constructed to operate for at least 100 years. The railway's quality is guaranteed for the long term, thanks to the special type of contract used and extensive co-operation with private parties.

The new HSL-Zuid track is 125 km long. 85 kilometres of the route consists of newly laid high-speed track. There are 170 structures, such as viaducts, bridges, tunnels and an aqueduct.

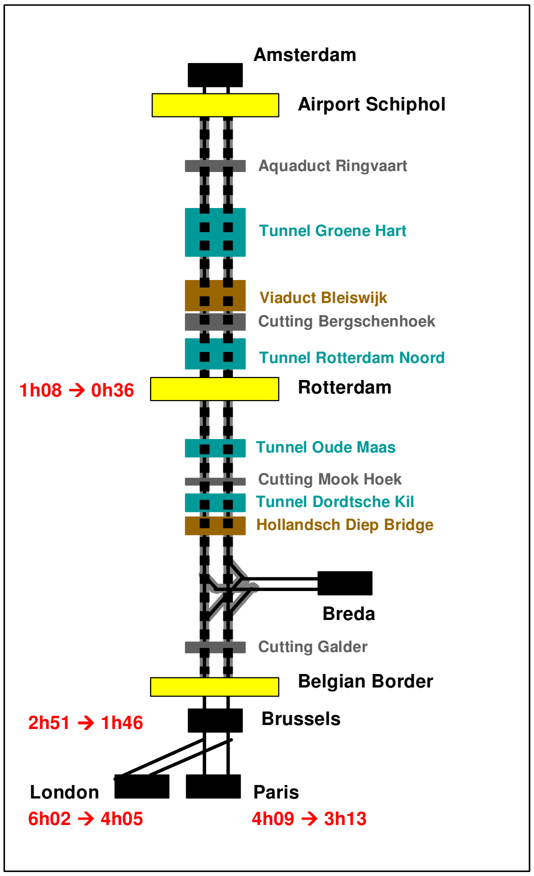


Figure 1. Travel time savings from Amsterdam

Most notable are the bridge over the Hollandsch Diep waterway (1200m) and the shield-driven tunnel (7160m) with a diameter of 15m underneath the environmentally protected "Groene Hart" area. This article focuses on the rail system (superstructure).

**The contract.** The HSL-Zuid Infrastructure Provider contract (IP-contract) is a Public Private Partnership (PPP) contract to deliver a service (railway infrastructure availability). The contract was signed in 2001 between the Dutch Government (State) and a consortium consisting of Fluor Daniel, Siemens, Koninklijke BAM-groep, Innisfree and HSBC (Infraspeed). It is a Design, Build, Maintain and Finance contract, where Infraspeed is paid via a performance fee over 25 years after a five-year delivery phase. The PPP contract is a custom-written contract form that uses commercial investments (equity and debt) to fund the cost of construction and operation of the high-speed rail superstructure. The Infraspeed consortium secures and uses these funds through a special purpose company formed specifically for the project. This company delivered the infrastructure to meet a functional and performance specification. Once certified and in service Infraspeed makes the railway available for train operations, with responsibility for stewardship, maintenance and renewals over 25 years. Payment is based on the availability of the railway for train services, and was only released once certification of the superstructure was complete. On behalf of the Dutch Government, the HSL-Zuid project organisation (HSL) acted as the Principal for this contract during the five-year delivery phase.

At the signing of this IP-contract, the HSL-Zuid project was fully focused on the construction of the civil substructure, Dutch national railways had just been split-up, the European Technical Specifications for Interoperability (TSIs) were still under development and transportation safety was becoming a "hot" topic in the Netherlands. Five years later, at IP-contract delivery, the HSL-Zuid project organisation had completely changed, a new Railway Act had come into force, the new Dutch railway infrastructure manager, ProRail, was preparing to manage over the IP-contract and the national construction sector had reorganised, after a public inquiry into illegal price-fixing deals. In these five years the environment of the project completely changed, whereas the project objectives remained the same and Infraspeed achieved the design and construction of the new high-speed infrastructure.

## The Bermuda Triangle

The Bermuda Triangle has a magic appeal. Those clients who are in perfect control are supposed to "smoke cigars" in the Bahamas, while their unfortunate contracted colleagues are managing the daily business. Conversely the Bahamas are located within the Bermuda Triangle (Bermuda, Miami, Puerto Rico). More than 70 vessels and aeroplanes are claimed to have disappeared here without any trace during the past 100 years. The Bermuda Triangle seems to act as a black hole.

Within a project there is also a Bermuda triangle (see figure 2). Avoiding the black hole of the Bermuda triangle is exactly the challenge of applying Systems Engineering to a PPP contract.

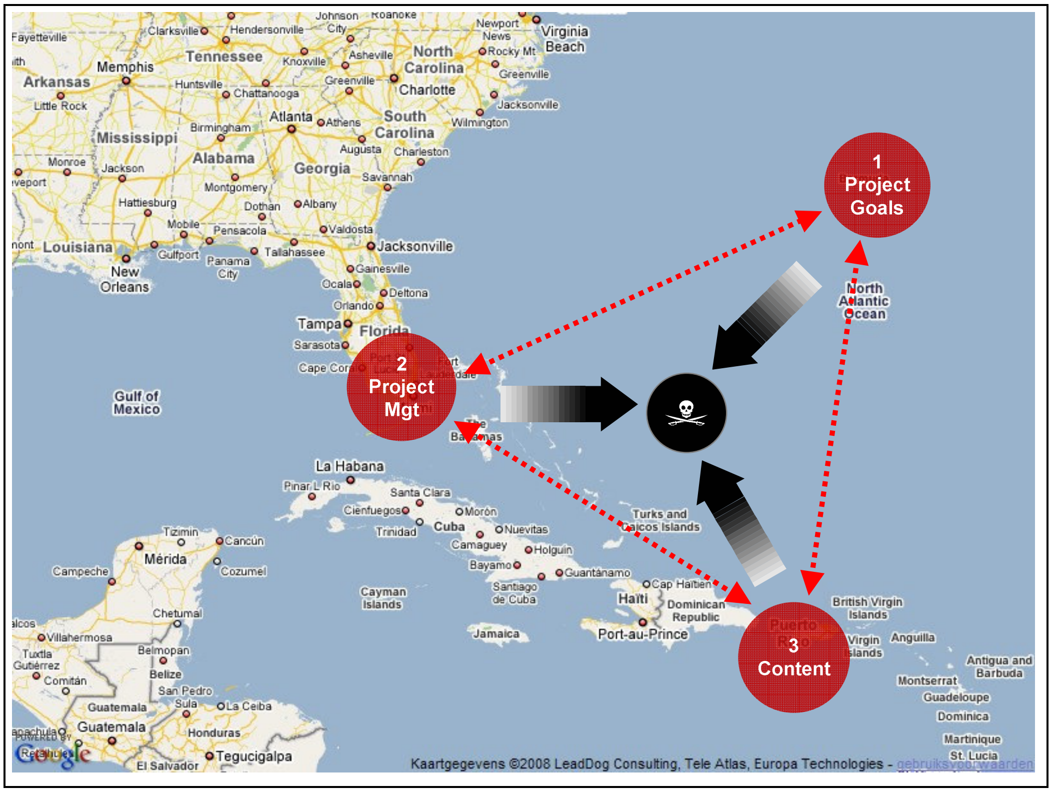


Figure 2. The Bermuda Triangle

**Project Management** in a PPP-environment asks for distant control by the Principal. Contracting "design, build, maintain and finance" to one Supplier means the Supplier needs maximum control to achieve the project goals and make profit at the same time. The Principal should not interfere with "how- to" questions, unless the final result and the project goals are endangered. Any interference can change the risk balance. The distant control mode sounds like smoking cigars in the Bahamas.

**Project Goals** are the compass for a PPP. In traditional contracting it is custom that the suppliers provide the building blocks for a project and that the Principal alone takes full responsibility to define and achieve the project goals. With a service-delivery contract, it is of vital importance that the Principal's project goals, including its stakeholders, are aligned and set at the right level and that the project goals of all suppliers are fully aligned with those of the Principal. Once there is major unknown variance in the Project Goals, the project will get lost in the black hole of the Bermuda triangle. This variance is comparable to the variance of the magnetic North at the Bermuda Triangle.

**Content** is about the real world. For every project there are a number of key parameters which are relevant to achieve the desired project goals; e.g. in seeking the transportation modal shift the train speed and headway are critical parameters in achieving the desired journey times. These key project parameters require proper attention from a content point of view. This especially holds for those parameters that cannot be fully controlled by the Supplier, but are also influenced by e.g. interfacing parties, or the environment of the project. When the required level of control on the content is not properly understood and managed, the view on the key project parameters will become unclear, just like the many theories on the Bermuda triangle prevent understanding of the real events. What is gossip, what is not?

**The paradox** of the model lies in the inherent contradiction between distant project management and hands-on content involvement, which asks for an active and sometimes in-depth interaction between all parties involved. Moreover the variance of project goals is often implicit. If one of the legs of the triangle is not in balance, the triangle collapses into a black hole. How then to keep the balance? How to achieve the peer level of interaction between parties?

The transparency and phased approach of Systems Engineering supports achieving this balance and peer level interaction. The lessons learned from the HSL-Zuid project are dealt with by examining the following themes: Organisation, Control, Innovation and Life Cycle incentives.

## Organisation

When considering how the co-operation between HSL and Infraspeed is maintained during the IP-contract we have some questions. What are the main drivers in the IP-contract? What is the approach? Which stakeholders are playing a major role in the delivery of the project?

**Contractual drivers.** As with most PPP-contracts, the main paradigm of the IP-contract is the focus on the delivery of a service, requiring Infraspeed to make available a high-speed rail link at a fixed date in accordance with predefined boundary conditions and other contractual requirements. It is this simple line that already defines the main project goal and the rules of engagement between parties. These contractual drivers provided the HSL organisation with a clear steer, resulting in three initial starting points:

1. a hands-off mindset in order not to take over any risk;
2. the fact that Infraspeed holds design authority meant that HSL would not formally approve Infraspeed's design solution;
3. the conclusion that a monitoring programme needed to be established to be able to spot delays or potential non-compliances at an early stage.

Though the initial starting points remained valid, the approach and methodologies used have been adapted during the course of the project, in order to achieve an effective co-operation

**Approach.** At the start of the IP-contract HSL already applied a "remote" Quality Assurance approach towards the civil contractors. This Quality Assurance approach means that, contrary to a more conventional quality assurance approach, where the Principal checks and approves the deliverables of the Supplier, it is the suppliers themselves that assure their own quality through proper quality control processes. The role of the Principal is restricted to the verification of the Supplier's Quality Assurance.

With all civil contracts being of the 'design & construct' type, and the IP-contract in place for the high-speed superstructure, this philosophy could be adhered to throughout the project. For the Quality Assurance approach towards the IP-contract a number of basic objectives were set:

- timely delivery of a defined service ("availability" performance);
- compliance with all contractual requirements;
- justification of performance payments in the "availability" phase; and

- justification of payments in relation to contract changes.

These objectives remained valid throughout the development phase, although at an operational level the focus of course changed over time as the project went through multiple phases. Though the principle of self-certification is simple, adhering to the principle is more difficult in practice.

In the initial years of the project, i.e. Infraspeed's design phase (2001-2003), HSL's focus was predominantly on monitoring the progress by Infraspeed. A monitoring programme was established with the purpose of detecting delays or compliance risks at an early stage. The monitoring programme was largely built around the execution and witnessing of audits and design reviews. HSL organised this by having an Quality Assurance expert panel which reviewed, on a 3-monthly basis, the proposed audits and reviews against the project management and system engineering processes that were stipulated in the IP-contract.

The drawback of this process approach is, however, that HSL was perceived as interfering with 'how-to questions' of Infraspeed. Meanwhile some content discussions were underestimated. The balance between goals, project management and content got disturbed. Hence the approach had to be adapted. With the project moving into a more delivery-oriented phase (2004-2006), HSL and Infraspeed adapted their Quality Assurance approach, which in the end resulted in the Incremental Compliance Demonstration process described in the next chapter. This process was an implementation of the Systems Engineering verification and validation activities.

**Changing World.** With a project such as the delivery of the IP-contract, which lasted five years, it is clear that the project environment will continuously change during its project lifecycle phases. The project organisation and control mechanisms are changing, stakeholders are reorganised, managers leave the scene and new leaders are appointed. New parties pop-up. Political events can and will happen outside the control of the project.

As a project organisation, HSL needed to act as the gateway between government and suppliers and between suppliers and stakeholders. This is a role that requires the skills to adapt to both sides. Staffing the teams with appropriate high level technical skills and social skills appeared to be extremely important.

In a changing environment, the necessity of the project organisation (HSL) to act as a gateway between government and suppliers creates tension when the organisation is too institutionalised and does not have the flexibility to change its operation. In these circumstances an institutionalised approach that mirrors a "department-oriented" project organisation provides less flexibility than a "task-force" approach. Conversely, whilst a "task-force" approach may provide a more flexible basis to manage moving targets, it contains the risk of becoming a moving target itself when there are no business rules that allow the organisation to change.

As every project phase and every outside change requires a different project approach, it is recommended to apply a project governance philosophy and resource strategy which allows the project organisation to change. Such a project governance approach should be sponsored at the highest level within the project and should assure that the organisational set-up is reviewed and adapted from time-to-time. Only if such a governance policy is in place, can systems engineering support the project goals in a changing world.

*As a conclusion, one may say that, using design reviews and audits in the initial stage of the project revealed major discussions, for example, with respect to the implementation of Systems Engineering processes, the Safety Case set-up and derailment prevention. However, this process approach did not enable influence on the content and created resistance. As such it was an* *essential step in achieving a breakthrough that led to the Incremental Compliance Demonstration process. Mutual trust increased, the content discussion was enabled. Transparent delivery and progress prevented HSL and Infraspeed from entering the Bermuda triangle.*

## Control

Apart from standard project control mechanisms, a number of additional control mechanisms were developed to ensure timely progress of the IP-contract. Some of the mechanisms were in place from the outset. Other mechanisms, like Incremental Compliance Demonstration, were developed during the project.

**Risk division.** The basis of the PPP-philosophy is a project risk division based on the ability to control a risk. Some risks can be better controlled by the Principal, whereas other risks can be better controlled by the Supplier. Table 1 indicates the basic risk division between Principal and Supplier for the IP-contract. The risk division principle is a key element in the rules of engagement and the behaviour of both parties.

Table 1: Risk division

| *Risk* | *Supplier* | *Principal* |
|---|---|---|
| Design | Solution selection, design, Change of standard, Certification | Civil interface information, Interface integration |
| Construction | Cost overruns, Delay, Technology, interest rate | Management of civils work |
| Operation | Maintenance, Renewal, Availability of service | Traffic, Latent defects in civils |
| General | "Entrepreneur" | Discriminatory change of law |

The risk division was input to verification and validation activities of both HSL and Infraspeed. Infraspeed had to demonstrate that the specified availability would be achieved. HSL had to take care of the basic traffic input parameters, such as train schedule and rolling stock assumptions.

**Project phasing.** One of the control mechanisms within HSL-Zuid of specific relevance to the Principal's team was the life-cycle model, provided by CENELEC standard EN50126. This standard provides for assurance of the Reliability, Availability, Maintainability and Safety (RAMS) of Railway Systems. The phased approach prescribes a number of phases, activities and milestones. At the beginning it was not fully understood that this life-cycle was, in fact, a jigsaw of HSL and Infraspeed activities. Both parties need a seamless systems engineering plan. As a consequence of the distant control approach to project management, system acceptance (phase 10 of EN50126) was expected to be part of the Supplier's scope like a turn-key project. The innovative character of the project (amongst others the introduction of new European train control system: ERTMS) and the operational interfaces to the existing traffic control did not, however, allow a turn-key approach. As a consequence, the authors found that project phasing according to EN50126 is a powerful tool. However, the content of deliverables can be confused by the splitting of responsibility for life-cycle products.

**Incremental Compliance Demonstration.** The IP-contract obliged Infraspeed to demonstrate all requirements by means of a Requirements Compliance Matrix (RCM). After issuing this RCM at the end of the development phase, HSL were contractually obliged to verify and validate the evidence for approximately 600 requirements within 10 business days. Both HSL and Infraspeed realised that this approach might put major risks in achieving the final certificate of availability and the start of performance payments. As a consequence the Incremental Compliance Demonstration process was developed to cope with this risk. A combined taskforce of HSL and Infraspeed was established to establish the Incremental Compliance Demonstration. For each requirement Verification and Validation mechanisms were agreed including detailed Pass-Fail criteria. For each requirement Infraspeed submitted an evidence package demonstrating the pass-fail criteria. The Pass-Fail criteria were related to several design stages according to the EN50126. This phasing, in fact, enabled an incremental approach. In combined sessions the compliance statements and evidence packages were presented and screened. These moderated sessions revealed a lot of confusions. The Principal then evaluated all packages. The entire process was supported by dedicated WEB-tools. Based on the demonstrated requirements an accurate progress control was enabled (see figure 3) at any time.

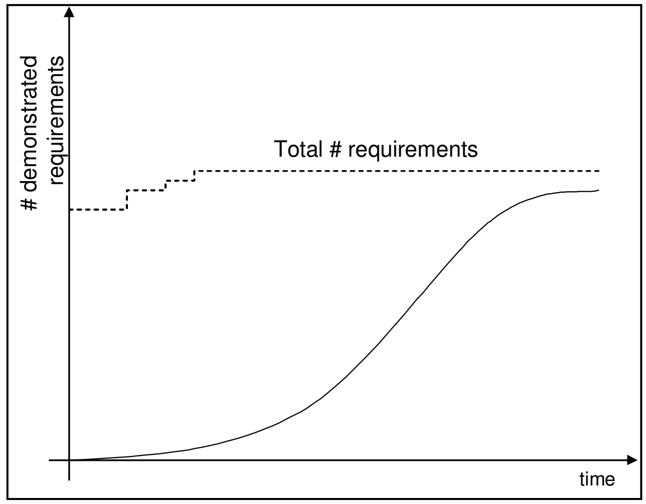

Figure 3. Compliance Progress

This progress control provided a link between the Systems Engineering approach and the Project Management approach. Many projects suffer from the 99%-problem: in the end 99% is completed but the remaining 1% takes more time and extra investment. Progress control on a requirements basis helps preventing the 99%-problem, keeps progress transparent and avoids entering the black hole in the Bermuda Triangle through focus on the project goals.

**Change Management.** The top element of the Bermuda Triangle concerns the project goals. The PPP-environment forced the Principal and Supplier to pay the utmost attention to the project goals and contract specifications. These elements can be in tension against each other.

On the one hand, a stable base was required to enter into such a large fixed-price contract. All risks must be calculated in advance based on the risk division principle. Although the IP-contract itself was quite complex, with an innovative Performance Payment regime to ensure availability during the operation and maintenance phase, the IP-contract itself comprised only about 600 requirements. Most change proposals arose from interface problems or ambiguous interpretation of contract clauses. However, at the end of the day the number of contract changes were quite limited compared to traditional contracts. It is in the interest of both the Principal and the Supplier not to change these type of contracts. This interest is supported by two incentives:

- Changes are expensive.
- Changes might be to the detriment of the performance payments.

As a consequence the initial contract should not contain too many anomalies. Once a change occurs it requires the parties to "dive into the content" before applying the incentive mechanisms. This requires a management style that allows progress without all deals being settled immediately. The mechanism of Systems Engineering and especially the (independent) verification and validation approach supports this effort with objective evidence.

On the other hand the project goals for the infrastructure project should fit within the overall transportation system. Considering our Bermuda Triangle model again, there are multiple goals and multiple parties in the Project Goals area. Keeping these goals and parties aligned along the course of the project is a special task, to be performed by the highest management of all parties involved. The significance of this task was under-estimated by HSL and Infraspeed. In particular the incentives for a timely delivery varied too much among the various contracts to ensure an integral delivery of the transport system. The financial bonus/malus mechanism for timely delivery for all contractors should be comparable.

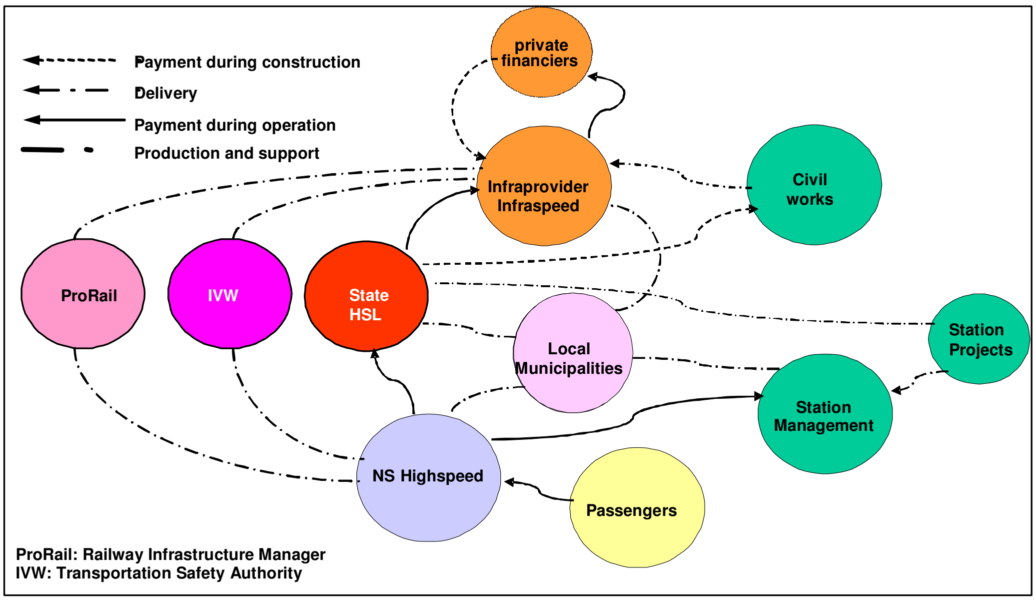


Figure 4. Stakeholders

**Role of stakeholders.** With such a large project (at least in Dutch circumstances) taking place in a densely-populated area, it is not surprising that the number of stakeholders in the project was huge (see figure 4). This varied from parties affected by the HSL project, for example stakeholders along the line who's assets were to be checked or even adapted as a result of electromagnetic interference caused by the new 25 kV catenary system; to local bodies with public responsibilities, like the water councils and local municipalities (including fire brigades); and bodies on a national level, each with their own public responsibility over the project, like the various Ministries, the railway infrastructure manager ProRail and the national transportation safety authority IVW.

**Example.** The following example details the involvement of the local municipalities and fire brigades in the role of independent verification and validation. In accordance with Dutch building legislation, local municipalities are responsible for granting building permits. Within the municipalities, it is the fire brigades that play an important role in the permit process on all matters that relate to safety. At an early stage of the project, in 1998/99, HSL started the discussions with all fire brigades along the line, with the aim of getting an agreed safety approach for the HSL project. This resulted in a jointly-agreed safety concept as the basis for the safety measures to be taken in the design of the overall HSL project. This jointly-agreed safety concept, with a more detailed safety concept for each civil structure, provided the project with a firm basis for the building permits of the civil structures. Not surprisingly, most discussions focused around tunnel safety. In the Netherlands, at that time, only three railway tunnels were in use and the country was facing projects with four railway tunnels for passenger traffic in the HSL-Zuid and four railway tunnels for freight traffic in the Betuweroute (the new freight route from the North Sea to Germany). At the same time, tunnel safety was a major discussion-point, not only as a result of a number of major tunnel accidents in Europe (e.g. the fire in the Channel Tunnel in 1996), but also because a number of serious and large accidents in the Netherlands had made parties more aware of their public responsibilities.

HSL and the fire brigades were able to manage these discussions on a national level, involving representatives of each regional fire brigade, instead of having to enter into local discussions. Thus, the regular meetings, separate discussions, safety studies and working groups provided a solid basis for the formal permit application, which was in the end a local matter.

The building permits that were granted for the civil structures included the conditions that Infraspeed had to adhere to in its design process. Here, HSL made a deliberate step to involve Infraspeed in the discussions with the fire brigades to agree on starting points and design choices. HSL, fire brigades and Infraspeed agreed the use of an independent body to assess final detailed specifications and inspections to guarantee implementation and operation of the systems. Although at the beginning of the permit process differences of opinion were multi-fold, the process that was organised as a joint effort, in the end provided consensus between all parties.

*Risk management is key to the control of Systems Engineering. However, in practice it was difficult to set-up a risk management process that explicitly allocated risks to stakeholders, who could manage the risk. It appeared that risks must be decomposed in order to enable a jigsaw of mitigation measures, which could be allocated to single owners. The Incremental Compliance Demonstration process helped in revealing the risk decomposition, simply by finding out who can influence what part of the content. Moreover, requirements control was shown to be an important tool in enabling project progress measurement. In addition, senior management must dedicate significant time to a process of keeping project goals and content aligned.*

## Innovation

One of the most remarkable aspects of modern times is the fact that technology used in projects with long development times is already outdated when a project is delivered. Although the development of a high-speed line is no rocket science, the question that remains valid is: where to stop developing?

**Contract.** The HSL-Zuid PPP-deal was the first of its kind in the Netherlands, and was already in the spotlight when the IP-contract was let in 2001, through the award of the “European PPP Deal of the Year" as well as the "European Deal of the Year 2001". A number of elements that were completely new to the Dutch railway industry were:

- The ‘delivery of service’ philosophy behind the contract, including the performance payment regime for the delivery of availability;
- The relationship between the Supplier and the Principal, with full responsibility for design and validation with Infraspeed on a lump-sum, turn-key basis, using EN50126 as the Systems Engineering standard;
- An Anglo-Saxon contract, in English, on the basis of functional specifications;
- The delivery of an integrated safety case to demonstrate safety for the HSL Assets; and

- The appointment of Notified Bodies with the responsibility for issuing a Certificate of Conformity for the HSL Assets in accordance with the European Technical Specifications for Interoperability (TSI).

Contract innovation poses a challenge towards the recruitment of resources that are able to handle such a contract and still maintain the know-how to communicate at a technical level. Here, the balance between project management and content (of the Bermuda triangle model) proves to be a delicate one and HSL undertook a number of measures to maintain a consistent approach by, e.g. training of employees, detailed screening of all in- and out-going correspondence and single-point responsibility for the IP-contract management within the HSL-Zuid organisation.

Notwithstanding all the measures taken, significant additional time in alignment meetings at management and working level is also necessary, to keep project goals, project management and content in balance.

**Certification.** The use of independent Notified Bodies (NOBOs) and Independent Safety Assessors (ISAs) to verify compliance with the TSIs was an important starting point for HSL's Quality Assurance approach. In accordance with the EU Directive 96/48/EC, compliance with the TSIs needs to be verified by formally accredited Notified Bodies. An important precondition here is that the scope contracted by the Supplier to the NOBO is the same scope as agreed between the Principal and the Supplier. It is worthwhile mentioning that the novelty of the NOBO process led to some discussion over the interpretation of TSIs on a number of occasions. This shows that the NOBO assessment process regarding the TSIs was not yet fully mature during the development of HSL.

An important advantage, however, of the NOBO process is the legal basis through which NOBOs obtain their formal accreditation and the definition of the approval process in the TSIs. In contrast to the position of the NOBOs, such a formal accreditation process does not exist for the position of the Independent Safety Assessor. The role of the ISA given in the IP-contract is to assess Infraspeed's Safety Case, meaning that the ISA has to verify whether the design meets the requirements and is fit for its intended purpose. This means that safety assessment is not only about design verification but also about safe usage of the assets in service.

The formal accreditation process for Notified Bodies provided an easy approach to the appointment of Notified Bodies by Infraspeed. The lack of a similar accreditation for ISA's had forced the necessity of contractual requirements on the selection of the ISA, requiring Infraspeed to propose an ISA, and to demonstrate its qualifications and independence. In return, this proposal had to be accepted by HSL.

Contrary to the verification of the TSIs by the NOBOs, HSL could not fully rely on the ISA's safety assessment report for the safety case and executed its own safety case acceptance process next to the ISA report. This process was justified for a number of reasons, the most important being:

- Although Infraspeed was fully responsible for the safety of the high-speed infrastructure, the safety case still required the acceptance of the State. This had been a deliberate decision in the IP-contract, to reflect the public duty of care of the State towards safety. For this purpose HSL wanted to form an integral judgement on the safety case in conjunction with the ISA report;
- Infraspeed's safety case contributed to HSL's integral safety case. This latter safety case demonstrated compliance with the project's top level safety requirements at a transportation-system level. HSL, as the integrator of this transportation-system safety

case, needed to verify whether the underlying safety cases provided the correct input and whether the safety case covered the scope of the contract;
- The lack of a standardised approach towards safety demonstration with a legally founded accreditation process and standardised assessment modules, as for the NOBOs/TSIs.

As for the NOBO assessment process, so is it of vital importance for the safety case, that the scope contracted by the Supplier to the ISA is the same scope as agreed between the Principal and the Supplier. Future projects will benefit from standardising the assessment process.

**Technology.** The development of the HSL transportation system contained a number of elements that were new to the Dutch railway sector. Interestingly, all of these innovations were in a different stage of development with different risk allocation when the IP-contract was let:

- To make it possible to travel at high train speeds on the soft Dutch soil, HSL developed a concrete, settlement-free plate which was constructed by the civil contractors. The Rheda-2000 ballast-free track system and its interface with the settlement-free plate were built by Infraspeed. The Rheda track was a proven system but, importantly, is new in its application in the Netherlands. In the end this new application was supported by special endurance tests.
- The selection of a 25 kV AC 50 Hz traction power system (which was simultaneously built on the Betuweroute), in contrast with the Dutch national railway network which applies a 1500 V DC system. A 25 kV traction power system is in itself a proven technology. However, its particular application in the Netherlands was again new and proved to be complicated as a result of multiple electromagnetic compatibility (EMC) issues that involved many interfacing parties. For a significant part this risk stayed fully with HSL, e.g. where the 25 kV system runs for a considerable distance parallel to the existing 1500 V DC system of the conventional railway network. This required a number of technical measures in the conventional network. A dedicated EMC Interface Matrix, identifying sources and victims of electromagnetic interference, supported the management of EMC risks.

Figure 5. HSL-Zuid

- The new European Train Control System (ETCS) and GSM-R communication system, together mentioned under the European Railway Traffic Management System (ERTMS). The ERTMS system was under development by the signalling industry at the time the IP-contract with Infraspeed was signed. When Infraspeed delivered the high-speed infrastructure the ERTMS specifications were under change. An additional handicap proved to be the fact that requirements for real configuration testing and safety qualification testing, which are compulsory for the delivery of command, control and signalling systems, were not yet unambiguously described in the applicable standards.
- Derailment was considered to be one of the most serious safety risks for the HSL. To investigate derailment causes and mitigation measures, HSL initiated a significant number of studies, including the development of derailment containment measures. After contract signature it was up to Infraspeed to demonstrate compliance with the numerical

risk targets for derailment. In the end, the high derailment safety risk requirements necessitated the application of a concrete plinth between the track rails along approximately 50% of the track length. Extensive international statistics have been consulted. Uniform interpretations were, however, difficult to make. Future projects might benefit from compilation of a consistent data set of international safety statistics.

The technological innovation on HSL gives rise to some interesting observations. First of all, making deliberate choices for innovative solutions at an early stage of the project, as the HSL did, inevitably leads to the necessity to either keep certain risk with yourself (as with EMC), or, to be prepared to participate at a content level where necessary. As an example, HSL made a deliberate choice to participate in the discussions on derailment risk analysis during Infraspeed's design phase.

Secondly, when basic design choices have already been taken, or when long lead items need to be ordered at a very early project stage, the question arises 'what is left to system engineer?'. And finally, the question "where to stop developing?" at first sight only seems relevant for project managers whose decision is driven by the required freeze date in project planning. This question can easily turn into "when can we stop developing?" when multiple stakeholders are involved, when a design freeze does not result in an acceptable solution, or when technological progress is not as expected.

*Infraspeed demonstrated that it was able to incorporate the innovation, provide alternative efficient solutions and still comply with the requirements. Conversely, the authors believe that innovation requiring the involvement of multiple stakeholders, can not be specified turn-key in advance. Interfaces require "bubbles" of data to be transferred among parties. Innovation asks for freedom, which must be managed in a different way. A separate contract combining stakeholders and multiple suppliers in a common phased engineering approach might help.*

*In determining the level of detail required in the specifications, two questions are essential:*

- *do I know the price per function within sufficient accuracy?*
- *are interfaces sufficiently clear that parties can proceed independently?*

*Answering the first question could be an effective criterion to stop detailing, although in some cases a more detailed reference design is required to get a reliable estimate. For the second question: not all interfaces could be specified in sufficient detail in advance (e.g. space reservations for ancillary equipment in tunnels). Moreover, procedural agreements to overcome interface issues were hard to settle contractually among different suppliers.*

## Life cycle

There is a history of projects under-delivering because of short-term capital savings made at the expense of long-term performance, e.g. poorer reliability or higher cost of maintenance. When considered over the life of the use of the assets (typically 15 – 40 years for railway systems, and in excess of 100 years for civil works) such savings are often poor value. One argument offered "in favour" of the PPP contract is that it encourages long-term thinking about the assets or services being delivered. Proponents suggest that by giving the PPP contractor the risk for performance of the assets, they will evaluate the most cost-effective solution to delivery, based on the costs of initial capital investment and maintenance/renewal costs. "Life-cycle"-design and -costing are the terms frequently used to describe the process of evaluating solutions over the whole process of design, construction, operation, maintenance and decommissioning.

**Linking engineering to operations.** This concept of life-cycle design and costing is not a new one, but the IP-contract proposed to put it into practice in full. The main goals behind adoption of the life-cycle approach are: to achieve the high levels of reliability that would match those of air- (and to a lesser extent road-) travel and thus encourage modal shift to rail; and to deliver cost-efficiency in delivery of the assets, e.g. by eliminating "gold-plating" seen in other major projects. Achieving these objectives is founded on the introduction of a service-based contract that gives the Infrastructure Provider the financial incentive to provide railway infrastructure that has high availability throughout the whole of the operational life of the IP-contract (25 years).

**Performance Payment Regime.** Two mechanisms are used to deliver the life-cycle approach. The "primary" mechanism for its implementation is the performance payment regime, illustrated schematically in figure 6. The regime works by defining the conditions which the Supplier must

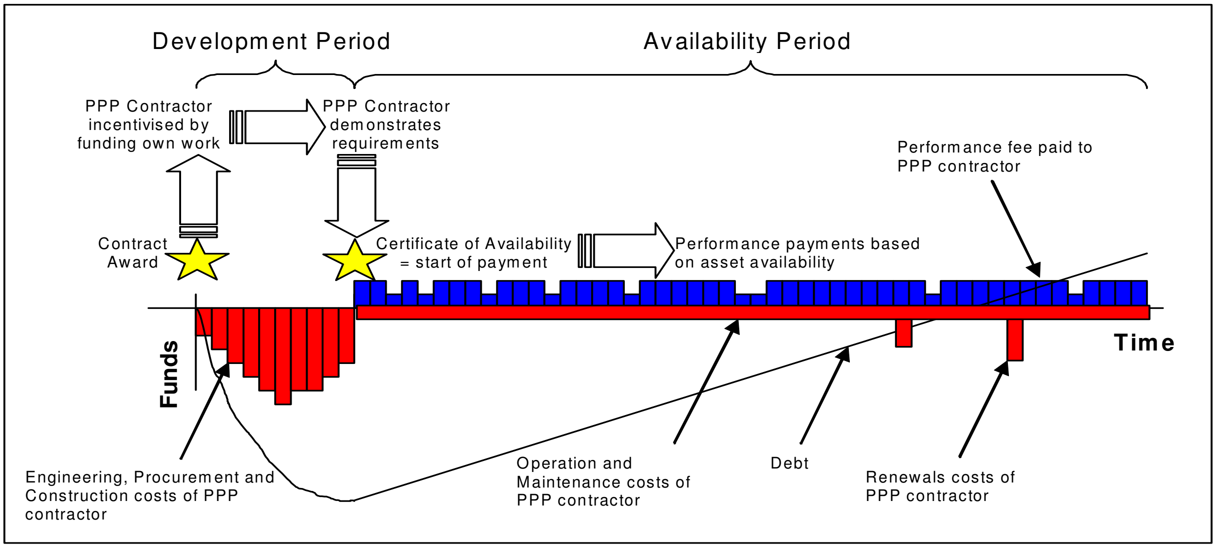


Figure 6. Performance Payment Regime

meet in order for payments to flow from the Principal, and is based on the simple concept that the Principal only pays for the railway systems when they are available for trains to run. Applying this concept means that the Supplier must first demonstrate to the Principal that all the functionality required is correctly implemented. Thereafter, payment is made monthly, on the basis of a maximum performance fee which is payable if the railway systems are fully available for train services for 99% of the defined service period (19 hours per day). In the event that train services are restricted in some way (through the imposition of speed restrictions or blocked track sections), penalties are deducted from the maximum performance fee. Penalties are also deducted for extended possessions and for reduced asset "condition", e.g. excess vegetation growth, graffiti or corrosion.

**Development process.** The "secondary" mechanism is the requirement to follow the EN50126 standard, during the engineering, procurement and construction (Development) Period and the operations and maintenance (Availability) Period. This standard provides a structured framework for balancing the requirements related to RAMS and to allow evaluation of the most appropriate solutions to meet these requirements over the lifecycle of the systems being developed. The IP-contract requires Infraspeed to work in accordance with this standard and to develop plans and products according to the phased approach specified.

Through these two mechanisms in the IP-contract, the Principal has handed over the task of optimising the lifecycle investment in the railway assets to the Supplier. Hence the Supplier had the freedom to evaluate and manage the initial "capital" cost of the solution against the long-term "operational" costs of performance and maintenance. The Supplier has responsibility for, amongst others, developing and implementing the processes for the apportionment of requirements, co-ordination of interfaces, integration of systems, project management, RAMS, verification and validation.

**Payment versus process control.** As expected, the "primary" mechanism (payment control) dominated, with Infraspeed working to the financial focus of getting paid at the target date. In this respect, the IP-contract was largely successful in incentivising delivery of the assets in accordance with the programme goals. The incentive of the performance payment regime (penalties applied to loss of availability), determined that availability calculations became dominant. Infraspeed directed most of their work on the availability of the assets to modelling the main sub-system and major component failures. As such a major effort has been spent on translating the traditional RAMS-calculations to the functional behaviour of the railway: speed restrictions, blockages etc. Despite the strong influence of other factors it appears to be difficult to incorporate the elements of human interaction, software behaviour, operations and renewal strategies in the final calculations. Since the Performance Payment Regime is integral to the profitability of Infraspeed, the information exchange is sensitive to commercial interests that can contradict with the required transparency for the lifecycle assessments.

These commercial interests appeared to limit the power of the "secondary" mechanism (process control during the Development Period) since it was less effective as described above, at promoting demonstration of compliance with the later CENELEC lifecycle phases (10 through 14). In generic terms the contractual process control deliverables helped to keep both parties sharp on the project flow. However the outputs of the life-cycle approach, the life-cycle thinking and related decisions did not become transparent for the Principal. This has been mitigated in part by the Incremental Compliance Demonstration (ICD) process, as far as the asset requirements were concerned for start of the payments. However, the longer-term economics of operation, renewal and decommissioning desired by HSL remain somewhat hidden.

**Hidden economics.** Why is the information on RAMS analysis, including assessments of the ease of maintenance and renewal, operability and human factors, and final de-commissioning and disposal of the assets somewhat hidden? These outputs remain significant to a client with overall economic responsibility for the railway assets over their full life (upwards of 100 years).

There may be a number of possible reasons for difference between the HSL expectations with regard to life-cycle management and the results achieved. It is notable in the comparison above with the ICD process, that the incentive to achieve "sign-off" of the Requirements Compliance Matrix was certainly stronger than the incentive to demonstrate the RAMS performance of the railway systems from a lifecycle perspective. There is a need to explore further the possible reasons for the differences in the outcomes: the contract requirements may have been insufficiently clear, HSL's expectation of the split of products to be achieved in relation to EN50126 may have been unreasonably onerous for Infraspeed, there may have been a lack of available data for RAMS that would prove savings over the Availability period, there may be a lack of proof or techniques for evaluating alternative solutions, or there may have been resistance within Infraspeed to make changes from the tender design.

**Balance.** We consider it possible that changes in approach are required in order to take account of the balances between the economic and financial constraints applied within a PPP contract.

For example, the financial requirements of the Supplier which govern the return period for the capital investment, are different from the economic requirements of the Principal for the long-term responsibilities for asset renewal, decommissioning and disposal. Some adjustment of the mechanisms for delivery and assessment are required. We need to compare lifecycle assessments of the economic demand forecasting arena, with the financial uncertainties of requiring the Supplier to assess maintain- and renew-ability of the assets. The objective should be to further improve the balance between the challenge to the Supplier against the overall value for money.

Reflecting on the Bermuda triangle model again, the project goals of improved affordability through long-term incentivisation for service-delivery have only been partly served by the management tool of the payment regime. The content needed to prove design decisions over the lifecycle of later project phases has not been fully revealed, leaving an uncertainty for the Principal in the longer-term. Nevertheless, this has been significantly offset by a much higher level of certainty over crucial implementation and operational phases.

*Choosing the availability as the key performance indicator and payment trigger, in particular for evaluating the life cycle, appeared to be beneficial to the Principal:*

- *a latent defect period of 25 years, which is considerably longer than with a conventional contract;*
- *predefined cost for 25 years availability service;*
- *25 years of maintenance risks with the Supplier;*
- *the Supplier has responded strongly to the incentive to deliver on time.*

*However, a certain mismatch between the life cycle and the contract length cannot be avoided. A contract length twice the average railway life cycle would serve the long term (upwards of 100 years) interests of a client, but is not feasible. The world changes too much over a railway's life cycle, to be able to capture all risks and changes in a bankable and stable contract.*

## Lessons Learned

Summarizing the lessons learned, the authors emphasize that project goals, project management and content should be tied closely together. This means:

1. Full hands-off project control can not be achieved even in a PPP-contract. The Principal always has to balance the project goals, the project management and the real content. Hence the Principal should incorporate sufficient skilled specialists in his team at the required abstraction level.
2. Project goals must be aligned not only at the start of the project, but also periodically during the whole project life cycle. All stakeholders should participate in special alignment sessions. Moreover, these sessions should deal with the real content. The stakeholders, including the Principal, must be subjected to matching delivery incentives.
3. Incremental Compliance Demonstration gives extra control opportunities to achieve co-operation and transparent progress compared to traditional audits and design reviews.
4. Risk decomposition, in accordance with contract responsibilities, is a pre-requisite to enable pro-active risk mitigation and risk control.
5. Availability, defined at a functional performance level, appeared to be a key parameter in keeping focus on the project goals and evaluating alternative solutions and trade-offs. However, changes may need to be made in order to correctly incentivise achieving value for money in the "life-cycle" objectives of operations and renewals.
6. Innovation should be treated differently from turn-key elements of the project.

## References


European Committee, *Council Directive 96/48/EC on the interoperability of the trans-European high-speed rail system*, 23 July 1996

European Committee for Electrotechnical Standardization (CENELEC) *EN50126-1: European Standard for Railway Applications: the Specification and Demonstration of Reliability, Maintainability, and Safety (RAMS).* CENELEC, Brussels 1999.

Hall, Ph., and Bendell, I., "HSL-Zuid Infrastructure Provider plots a new route", *Project Finance International*, Yearbook 2002.

HSL-Zuid, Semi-Annual Report to the Lower House, Progress report nr 5, Supplement: "The Public/Private Partnership for the construction and operation of the HSL".

HSL-Zuid, Semi-Annual Report to the Lower House, Progress report nr 9, Supplement: "Contract Infraprovider".

Korf, W., Innovative connection to the European Network, *Public Service Review: European Union*, Autumn 2001.

Maraini, E., "Time for a Re-Think of HS Rail Priorities", *International Railway Journal*, July 1999

Reina, P., "Tough Going in Low Country", *Engineering News Record,* June 30, 2003.

Zoeteman, A. and Braaksma, E., "An approach to improving the performance of Rail Systems in a Design Phase." Delft University of Technology.

Zoeteman, A. and de Weijs, P.R., "The HSL South Infraprovider Contract: contents, process and results", Innovations for a cost effective Railway Track, Published by Prom@in, November 2003.


## Biography


**Robert Audsley** is an engineer and management consultant specialised in the procurement and delivery of complex projects, with a strong interest in sustainable transportation. Between 1999 and 2007 he fulfilled a number of roles within the HSL-Zuid project organisation, latterly holding the position of Technical Compliance manager for the IP-contract. His experience spans the transportation and utility domains in the Netherlands, the UK, Europe and Asia. Robert holds an MEng in Civil Engineering and European Studies (1993, Aston University, Birmingham, UK)

**Erik Elich** is an independent consultant in change and engineering management. Apart from the public sector he gathered his knowledge and experience in the electronics, defense, medical, banking, and IT industry. Erik holds an Msc in Electrical Engineering (1984, Delft University of Technology) and is fascinated by the "suspense of old and new, between now and endurance ". His device is balance in change.

**René van der Vooren** is a consultant and manager of a consultancy and engineering unit within Movares. As project manager he was engaged in the HSL-Zuid project organisation from 1999 until 2007 in various positions and was appointed as deputy contract manager for the Infraprovider contract in 2005. Prior to joining Movares he worked as a process engineer for an engineering contractor in the oil & gas industry. René holds an Msc in Mechanical Engineering (1990, Delft University of Technology).