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Cost benchmarking of railway projects in Europe – can it help to reduce costs?

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Abstract

This paper highlights the methodology and preliminary results of the construction cost benchmarking of railway projects on EU territory. Benchmarking procedure is essential to learn from others, improve particular project areas and reduce costs in any project. For railway projects benchmarking is important for the comparison of unit cost per major cost drivers (i.e. cost of tunnels, bridges, etc.).

This methodology is applied to the case study, described in this paper, the first Danish high-speed railway line "The New Line Copenhagen-Ringsted". That project's aim is to avoid cost overruns and even make lower the final budget outcomes by looking for the best practices in construction and implementation of other high-speed lines in Europe and learning from their experiences.

This paper presents a benchmarking of nine railway projects, comparable to the Copenhagen-Ringsted project. The results of this comparison provide a certain overview on the cost range in different budget disciplines. The Copenhagen-Ringsted project is positioned right in the middle between cheaper and more expensive projects in the comparison of total costs per kilometre. Although its values in the discipline comparisons are not significantly differ from the values of the cheaper projects. The deeper analysis of project unit costs is still on-going, but the preliminary results show that the cost values of the projects located in the same geographical zone are slightly the same, e.g. this is explained by the use of the same construction companies presented in the market. However, unit prices in Southern Europe are lower that in Northern Europe.

1   Introduction

This paper highlights the findings of an on-going PhD research, and focuses on cost benchmarking of European high-speed railway projects. The obtained knowledge will be applied to the Danish railway project "The New Line Copenhagen-Ringsted".

The goal of this railway project is to increase railway capacity between cities Copenhagen and Ringsted by providing a high-quality and high-speed railway transport service for commuters. The project consists of a completely new double-track railway line with the total line length of 60 km and an operating speed of 250 km/h. According to EU directive 96/48/EC [1] high-speed definition this means that it will be a high-speed railway line – the first such project in Denmark – ready for passenger and freight

operations in 2018.
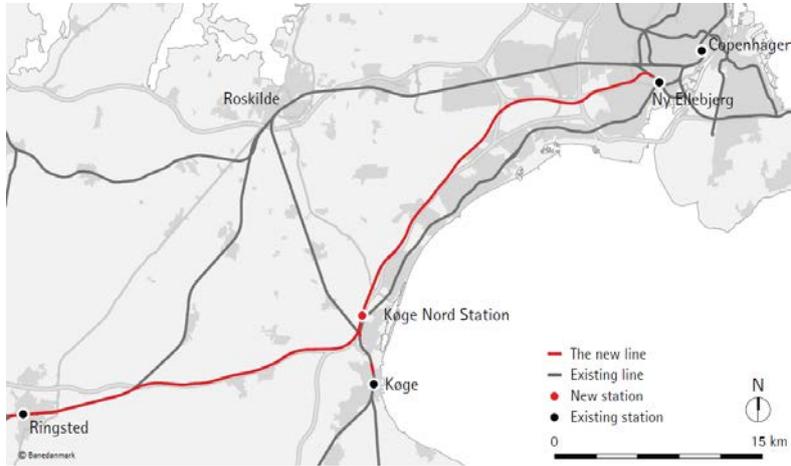
Figure 1: The map of The New line Copenhagen-Ringsted [2]

The pure available project's budget is EUR 1.1 billion (2011). This is distributed by 12 main cost disciplines, taking into account previous Danish experience in construction of motorways provided by the Danish Road Directorate budget model. Furthermore these 12 disciplines are distributed by specific units with market values, calculated by railway engineers from the Danish consultancy companies.

The summary of the budget is presented on the Figure 2 in percentage of total project costs.

Figure 2: Copenhagen-Ringsted budget distribution by main cost disciplines in %

The Banedanmark (Rail Net Denmark) as Infrastructure manager has a particular interest to this study, since they don't want to meet cost overruns experience in their project. Therefore, benchmarking of similar railway projects is considered as a reliable option to learn from the other experiences and do not repeat any mistakes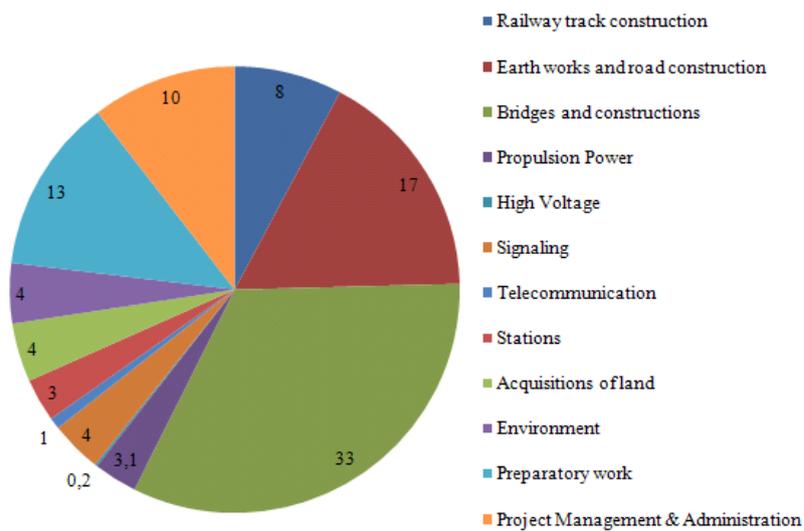 obtained from those. They have a vision that some amount of planned project´s costs can be saved, e.g. by involving into the construction of railway project skilled contractors, known on the international market; and applying state-of-the-art technology. Their hypothesis is that the involvement of international contractors to the Danish project may help to establish a competition between them and local companies and therefore win the better prices for several contracts. Moreover knowledge about material prices and new technologies from other projects will help to find out cheap and qualitative solutions also suitable for the Danish project.

1.1 The outcomes of this paper

This paper is built on the previous cost overrun and benchmarking experiences. It represents preliminary research of an on-going PhD study. The research differs from previous studies, since it goes deeper to the project budget investigation by main cost disciplines and focuses on main project's cost drivers, i.e. unit cost of railway materials and major civil structures. These are compared to Copenhagen-Ringsted estimated values and differences are analysed.

Use of benchmarking of similar European projects with best practices is not indicating that exactly their strategies will be implemented into the Copenhagen-Ringsted project. Sometimes it could be useful just for overall information.

To enable a positive benchmarking contribution to the current research, a database of high-speed railway projects was collected, including data on overall cost values, the number of physical components (tunnels, bridges, etc), contract types, and lists of consulting and contracting companies with recommendations from other infrastructure managers.

A few relevant high-speed railway projects were visited to achieve practical collaboration with infrastructure managers. The visits to construction sites brought a useful visual understanding of the project's size, quality and the technology used. There were also organized face-to-face meetings with particular project representatives with focus on the financial side of their project.

Furthermore, the breakdown of project's costs by disciplines was examined and compared with the Danish project. The disciplines were distributed by key performance indicators (e.g. price per unit) so as to set targets for future improvement.

The results of this research and lessons learned provide the guidance for current and future projects. The initial comparison by total costs of project's kilometre provides an overview of examined project position among others. Whereas the comparison of main cost disciplines shows areas of possible improvement if some costs are lower that the researched project costs are. In this case, project managers are able to find their cost position relative to other projects, and secondly they are able to come to conclusions about how to stay within planned budget in future or reduce some costs by using the outcomes of this research, e.g. total costs, cost distribution by main disciplines, and price values for main infrastructure supplies.

2   Cost overruns in the past railway projects

The construction of the new high-speed lines requires long planning procedures, skilled and experienced staff, and huge investments. The final investment costs for European railway projects vary between EUR 12 and 45 million per kilometre according to UIC Infracost report [3], depending on the alignment allocation, amount of physical structures, and difficulties during construction.

When planning the budget for new lines, making cost-benefit analysis and forecasting future profit, it is always difficult to predict the exact financial outcome of project. Many real-life examples of large infrastructure projects show that the initial costs were underestimated, and the final costs include a large percentage of cost overruns.

Many researchers are paying attention to this problem and trying to find explanations for it to share the knowledge with project managers and prevent such mistakes in the future.

Mette K. Skamris Holm in cooperation with Bent Flyvbjerg generated a database of 258 large transport infrastructure projects, the value of the sample was US 910 billion dollar (1995 year prices), projects included in the sample were built between 1927-1998. In her thesis [4] she pointed that the sample had to be large enough to allow statistical analyses of cost overruns and benefit shortfalls, although 9 out of 10 projects had cost overruns. There were 58 rail projects among the others with an average cost overrun of 44.7%, ranging from -46 to +200%. There were no significant differences between urban, high-speed and ordinary rail projects.

Similar and more detailed research was performed in the PhD thesis [5] by Morten Skou Nicolaisen under the Danish research project UNITE (UNcertainties in Transport project Evaluation). He has observed 20 railway projects in Europe and found out that about 16 projects were underestimated with the inaccuracy interval from 0 to 60% as it is shown on the Figure 3.
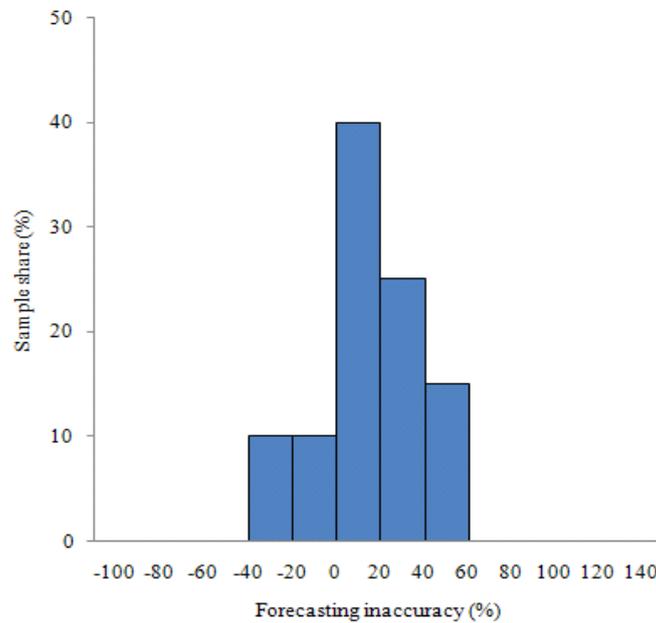
Figure 3: Forecasting inaccuracy in the railway project from the sample of 20 projects [5]

Bent Flyvbjerg in his works has widely discovered problem with cost overruns in Large Scale Transport projects, as he named them – Megaprojects. He focused on problems in megaproject policy and planning and their causes and possible cures, where he argued that a main problem in megaproject development is pervasive misinformation about the costs, benefits and risk involved. In his paper [6] he explores the causes of misinformation and finds that political-economic explanations best account for the available evidence: planners and promoters deliberately misrepresent costs, benefits and risks in order to increase the likelihood that it is their project and not the competition's, that gain approval and funding. As an example, he provides the overruns of the High Speed 1(also known as Channel Tunnel Rail Link) project in UK, which actual construction costs were exceeded by 80% compare to the initial estimates.

Currently, the causes of budget overruns are divided into four main groups, according to Flyvbjerg paper [7] as follows:
1. Technical explanations (forecasting errors, price rises, inadequate planning procedures);
2. Economic explanations (underestimations due to lack of resources or incentives, poor financing or contract management);
3. Psychological explanations (optimism bias among local officials);
4. Political explanations (deliberate cost underestimation).

Mistakes in project estimates comes from a lack of experience, therefore the tendency to make correct project estimates can be minimized by learning from the past projects. To avoid cost overruns it is very beneficial to perform cost benchmarking of similar projects or similar cost disciplines to get additional knowledge in the chosen field of interest and further implement gotten knowledge to the real project.

3 Benchmarking use in the earlier works

Benchmarking as a tool was used in different studies related to high-speed railway performance among the variety of constructed lines and those still under construction. Campos and de Rus did several studies on high-speed railway [8]. For their research they have collected database with 166 railway projects existing at the beginning of 2006 in 20 countries. On the Figure 4 is shown the data elaborated from UIC HSR database, where are presented the cost of HSR, including infrastructure and superstructure costs, but excluding the planning and land costs. In their paper they argued that total investment cost for high-speed project consist of planning and land cost (5-10%), infrastructure construction costs (10-25%), these vary and depend on the complexity of terrain, e.g. in the hilly areas these may double the costs up to 40%; and finally superstructure costs add 5-10% to the investment.
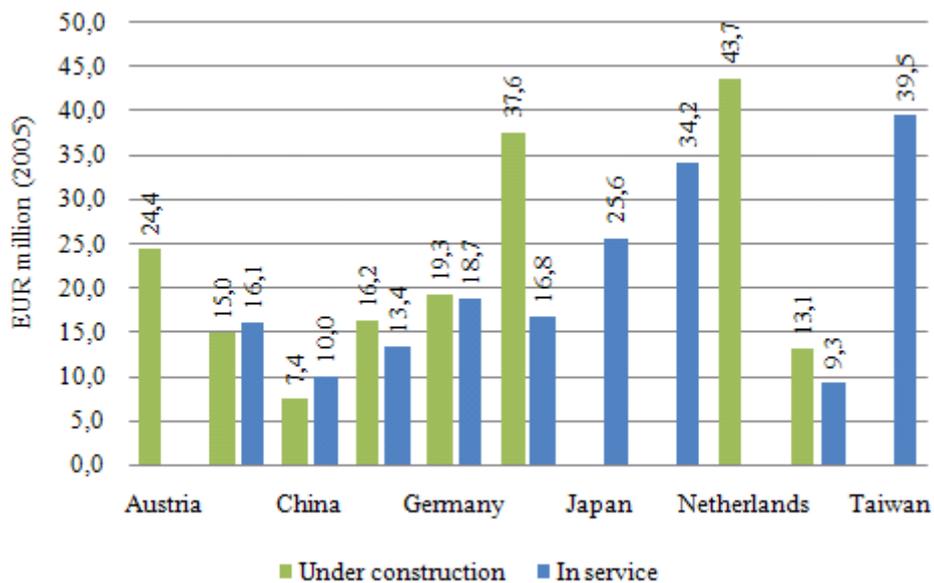

Figure 4: Average costs per kilometre of new high-speed line (elaborated from [8])

From the Figure 4 is seen that France and Spain have slightly lower costs among others. The authors explain it by the existence of less populated areas where these lines were performed and also difference in construction procedures, e.g. in France they prefer to use steeper grades rather than building tunnels and viaducts. While in other countries high-speed lines were implemented in more densely populated areas, where were various challenges in the construction because of it, e.g. Italian and Belgium HSL networks.

Campos and de Rus also argued that the construction cost per kilometre (excluding planning and land costs) in 45 already constructed projects varies between EUR 6-45 million, whereas in 24 projects in operation the cost varies between EUR 9-39 million (2005). This range can be explained by difference in geographical conditions between these countries as well as in cost levels, e.g. average costs in Southern Europe are lower

than in Northern. They didn't see significant difference in construction costs between constructed and projects under construction.

Another research and benchmarking process on high-speed railway lines was done by consultancy company Steer Davies Gleave [9]. The report was done to compare the performance of High Speed 1 in UK with other projects and find out why the cost of this line are much higher than in other countries, e.g. it is 7.6 times expensive than the Spanish line Madrid – Lerida. From their comparison they removed the costs of rolling stock and financial costs. Although HS1 was not the best practice to compare with, firstly, the cost in UK for construction, land acquisition and labour are much higher than in other countries, secondly, the project came out with construction cost overruns because of the wrong planning of initial budget [6] [7].
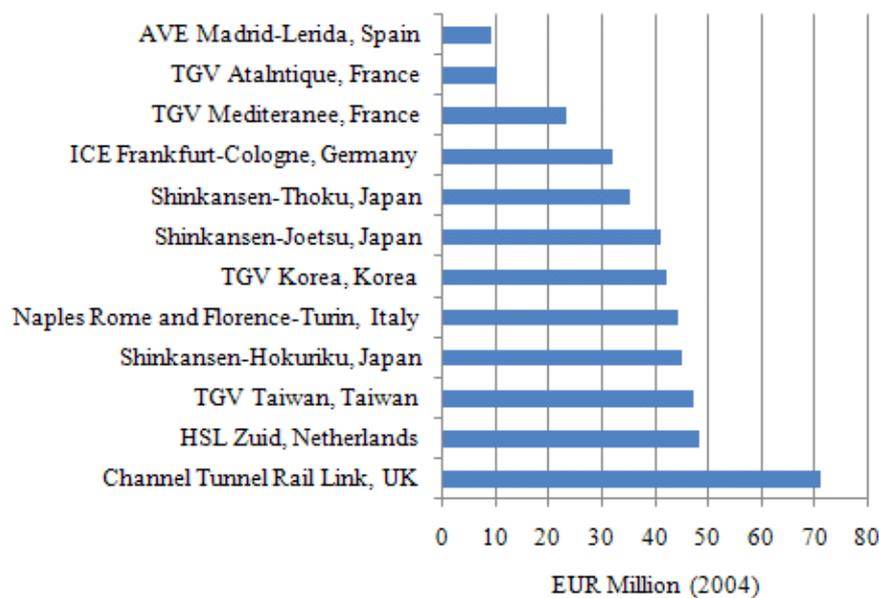
Figure 5: The costs of HSL routes, EUR/kilometre [9]

The authors [9] explain the difference in cost range between the projects by different factors. Firstly, by different proportions of the route that are in tunnels or in viaducts - those are main cost drivers for any project and they rise the costs for 4-5 times, secondly, the costs of land expropriation varies between countries significantly, thirdly the difference in environmental, safety and planning processes also brings additional costs. They also concluded, that countries with major high-speed construction programmes have lower costs compare to the countries with such single projects.

3.1 Previous benchmarking studies in Denmark

The benchmarking procedure for Copenhagen-Ringsted railway was conducted on a top-level before, in 2009, and described in the report [10]. While this project was on a planning phase and project management needed additional knowledge for establishing

project budget. The choice of projects was based on the close geographical location (close neighbours, i.e. Germany, Netherlands, Finland and Sweden), because of the similar approach in construction and common construction market.

1. Betuwe route (the Netherlands) – freight railway line of 160 km
2. Nuremberg-Ingolstadt (Germany) – new railway line of 171 km
3. UIC research and their database findings
4. West Cost line to Falkenberg (Sweden) – new railway line of 13 km
5. Kereva-Lahti (Finland) – new railway line of 63 km

All these projects were not straight-forward comparable to the Danish project, e.g. German project consisted of a high ratio of tunnels, construction of these raise the total costs significantly; whereas the Dutch project was double expensive from initial estimates, because of wrong cost planning and construction time exceed by 2 years. This means, that German project might be cheaper than Danish project, if from the comparison there would be extracted costs per tunnels. The obtained results were not further analyzed.
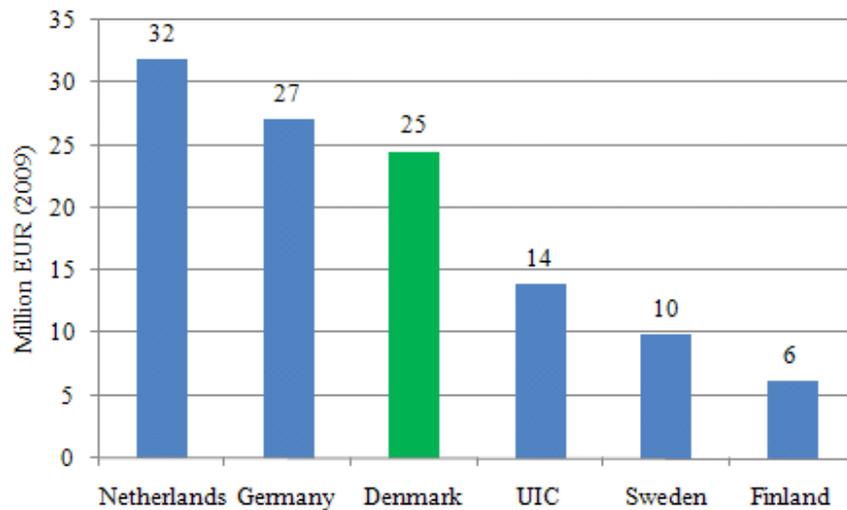
Figure 6: Construction costs of double track railway lines, EUR million/km [10]

3.2 Main cost drivers

What influences the cost of project? Different factors form the final estimations of project budget. The costs depend on the alignment of new line, e.g. densely populated areas vs. rural areas, flat terrain vs. hilly terrain, etc. Amount of civil structures and its complexity require additional funds as well. Not least to mention the overall country economical level, e.g. price level of the Northern Europe vs. Southern Europe.

According to UIC research [3] following cost drivers influence the costs of project and some of them may influence final financial outcomes:

1. The cost of speed

The cost of speed depends on reliable construction of track and catenary, save signalling system, costly earthworks and civil structures due special design parameters: large curve radii, large distance between centres of track, low gradients.

All those elements are costly, but they support journey on higher speeds.

2. *The cost of capacity*

Project complexity influences cost increase, while the volume of traffic for which the infrastructure is required needs multiple track, shorter headway and block distance, more switches, etc.

It was noticed, that cost of HSL dedicated to passenger traffic is for 20% lower than those of mixed-traffic HSL, because mixed lines requires additional materials and safety issues related to the freight trains.

3. *Electrification and signalling/control systems*

Electrification adds to project complexity and thus to investment, maintenance and renewal costs. Investment in catenary and power supply makes up about 10 % of project cost.

4. *Project schedule*

Most of the projects analysed in UIC Infracost study [3] took about five years to construct. The construction time depend mainly on the length of the longest tunnel and of the project environment – difficult geology, traffic interference and construction in urban areas. Though, long construction time also brings additional costs to any project.

4 Method

Benchmarking is used as a main method for information collection for this study.

The term "benchmarking" appeared into the business lexicon in early 1980's and was used to call the measurement process by which to conduct comparisons. The Xerox Corporation has used benchmarking to measure their products and services against the other competitors and afterwards they were able to perform even better on their market. The experience in benchmarking by Xerox lay down as a good example for other companies, as well as it was described and analysed in various research papers [11].

There exist dozens of benchmarking definitions, but they all have a common meaning, that this is a process that helps to learn from the best practices in a particular area and implement benefits to the company business that initiates this process.

However following benchmarking definition was met in the literature and it comprises with the current research:

Benchmarking is a powerful management tool, it opens organization to new methods, ideas and tools to improve their effectiveness. Companies use this methodology to improve practices, reduce costs and increase the size of total market. [12]

There exist plenty variations of benchmarking application to some projects, i.e. methodology of benchmarking may consist of the following steps [13]:

- Identification of the subjects (research areas) and partners for benchmarking
- Collection of relevant data which emphasizes the gap in performance
- Identification of the reasons for the performance gap and analysis of best practice
- Development of an action plan and its implementation
- Adaptation of best practice in the current organization
- Updating the progress of performance relative to best practice

Practical implementation of benchmarking in the current research was performed into few levels. Initially there were selected different high-speed railway projects comparable to Copenhagen-Ringsted railway. They were benchmarked at the top level by collecting all relevant data from literature and the Internet and forming the database and top-level

comparison of construction costs per kilometre of the selected lines..

For the initial comparison were selected 19 railway projects different railway projects in Europe, built in the past 20 years and few of them still under construction. The focus was based on project's complexity (fewer amounts of complex civil structures), relatively flat terrain, location along motorway and preferable outside densely populated areas.

Table 1: Main characteristics of the projects examined

Number of projects	19 projects in 9 countries
Observed projects	HSL and conventional railways
Length	10 – 621 km
Traffic, # tracks	Mixed and passenger, double
Designed speed	200 – 320 km/h
Physical requirements	Flat terrain, allocation along the motorways, small number of complex structures (tunnels)
Overall budget	488 – 9.58 M EUR
Value per km	11.47 – 62.72 M EUR/km
Construction period	1993-2025

Relevant projects are presented in the table below and some of them are observed further in this paper.

Table 2: Review of the projects examined

Country	Projects	Length, km
Belgium	HSL 1 (Brussels-French border) HSL 2(Leuven-(Ans) Liege) HSL3 (Liege-German border) HSL 4 (Antwerp-Dutch border)	75 66 36 87
France	LGV Rhine-Rhone LGV Est européenne LGV Méditerranée	140 300 250
Germany	HSL Cologne-Frankfurt HSL Nuremberg-Munich HSL Erfurt-Leipzig/Halle	177 171 123
Italy	HSL Rome-Naples HSL Turin-Milan HSL Milan-Bologna	205 125 182
The Netherlands	Hanzelijn (Zwolle-Lelystad)	50

Norway	Gardermoen Line (Oslo-Eidsvoll)	64
Spain	HSL Madrid-Barcelona	621
Sweden	BanaVäg i Väst (Göteborg-Trollhättan)	75
	Mälarbanan (Barkaby-Kalhäll)	10
The United Kingdom	High Speed 1 (St Pancras - Channel Tunnel)	108

There were difficulties in getting some information related to the true construction costs, amount of physical structures, etc., which is why the next step in benchmarking process was begun.

The second step was based on a questionnaire for infrastructure management and other engineering organizations responsible for project realization, e.g. the French company, Inexia, was responsible for LGV Rhin-Rhône, and the Belgian company TUC Rail was responsible for all Belgian HSL construction. The questionnaire consisted of four parts:

- Project overview, i.e. all relevant data concerning planning and construction time, initial and final outcomes of particular projects, pricing year, and the agency responsible;
- The project's physical structures, i.e. exact numbers of tunnels, bridges, viaducts and other relevant structures, and their geometric parameters (length, breadth, height);
- Review of industry, i.e. contract types, names of companies that participated in the construction and planning;
- Construction costs, i.e. distribution of construction cost in the different disciplines (tracks, power supply, telecommunication, signalling, administration, etc.). The budgeting model of Copenhagen-Ringsted project was put there as a template.

The data received through questionnaire was also not enough for some projects, moreover there were decided to focus only on few most similar projects in the detailed research. Therefore there were performed final benchmarking step. The third step consisted of live meetings with relevant persons from selected projects, who was able to answer all questions, related to financial and physical project parts. The main cost disciplines were distributed by major cost drivers, which may influence the total project budget and compared.

All the data received through the questionnaire and other meetings was analysed and is presented in this paper anonymously in the next chapter.

5 Results

The response from questionnaire recipients was about 70%, e.g. two French projects rejected participation for reasons of confidentiality; three German projects presented very basic data without any cost distribution for the same reason; one Norwegian project couldn't to provide any values, because all relevant data was stored in archive; two projects from the initial selection rejected participation without giving any reason. Although this paper focuses on the comparison of those projects from the sample, which provided all the requested information.

5.1 First benchmarking level

The first benchmarking level consisted of project's total cost comparison per kilometre of railway line. The comparison is shown in Figure 7, where are included only 9 projects from 19 presented in the Table 2. All the projects presented here in the anonymous way and have a constant letters instead of real project names. Project "D" represents few projects all together within one country, this is because all the data was provided by the engineering company, responsible for the construction of the entire HSL network in that country and, thus, they had provided only common statistics on our request.

The average value for this sample is EUR 28.14 million. The position of the Copenhagen-Ringsted project among others shows its location almost in the middle of this sample with an average value of EUR 19.79 million. The last five projects on the right-side have higher costs than the Danish project, that might be explained by several different factors, e.g. project complexity with costly structures, geological challenges during construction, construction during existing railway operations, and reconstruction of additional infrastructure elements due to local legislations. E.g. project "L" consist of reconstruction of neighbouring motorway and the costs of its construction is difficult to extract from the total costs. The same was true for the project "A" in our initial comparison and therefore to price per kilometre was about EUR 20.00 million, when we discussed the budget with infrastructure manager representative and deducted the motorway costs, this project took the first place in our comparison. The same might be true for the project "L".

Thus the projects with lower cost values, located on the left-hand side from Copenhagen-Ringsted project, represents best practices also in terms of costs. These projects in physical length exceed the length of Copenhagen-Ringsted, moreover they all come from countries, where high-speed railway transportation is developed during many years, this also means that they know how to save money on construction. It is important to learn from them about their cost distribution, work with contractors, material purchasing process and some other items that might influence such low costs per kilometre.
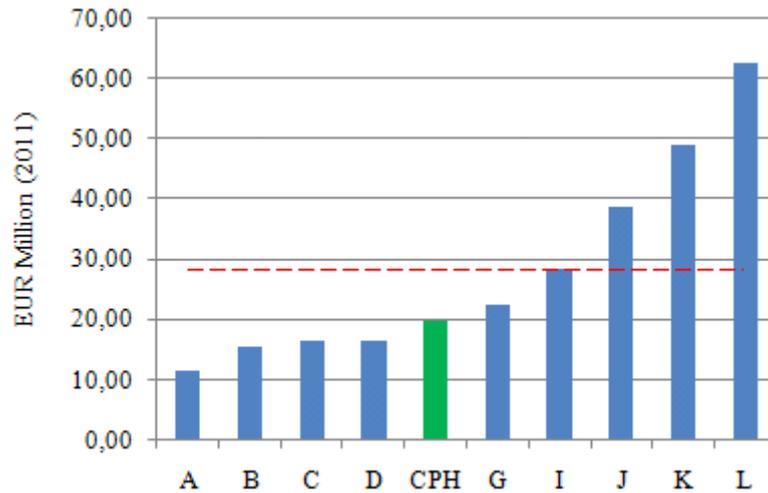
Figure 7: Comparison of total costs per kilometre for selected projects

On the Figure 8 is shown the physical contents of observed projects, which was divided into tunnels and other civil structures, i.e. viaducts and bridges. Although, all projects have higher ratio of bridges and viaducts and only projects "B" and "I" consist of higher amount of tunnels relatively to other projects. Construction of tunnels is long and costly process, that is why tunnels are always raise the overall project costs. There are two types of tunnels in all the projects – natural tunnels, where were used boring machines or explosions (used only outside populated areas) and artificial tunnels, where the earth for tunnel area was digged out and some amount of that earth was used to cover the placed tunnel tube. Construction of artifitial tunnels is cheaper than natural tunnel construction, because in this case the earth might be reused further to cover the tunnel and there is no need to use expensive borring machines.

Thus the project "I" consist of 90 artificial and 33 natural tunnels with the total length of 10 km and 27 km respectively, whereas the project "B" consist of 83 tunnels with length of 86 km in total – they both are located in the different sides of Copenhagen-Ringsted project, which will consist of 4 cut-and-cover tunnels with the total length of 2 km.
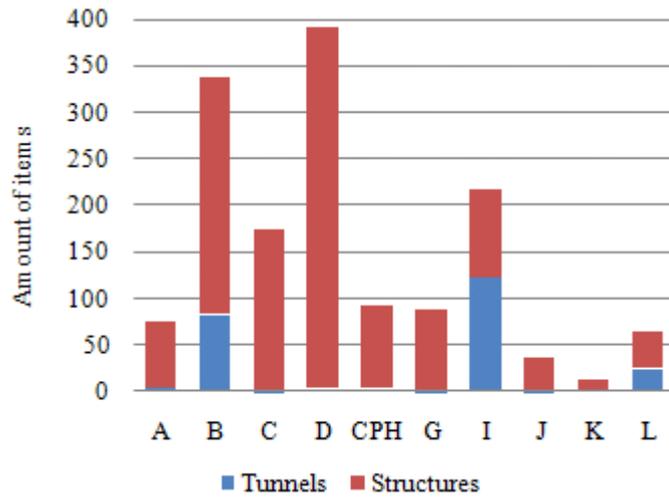
Figure 8: Amount of civil structures in selected projects

When comparing the cost of selected projects and its physical contents on the Figure 8, it is seen that cheaper projects consist of higher ratio of civil structures than more expensive projects from the right-side. Therefore we tried to analyze the available budget distributions of these projects and found out that, e.g. Land acquisition and Signaling discipline costs of these projects are slightly higher than on the right-sided projects, as it is shown on the Figure 9.
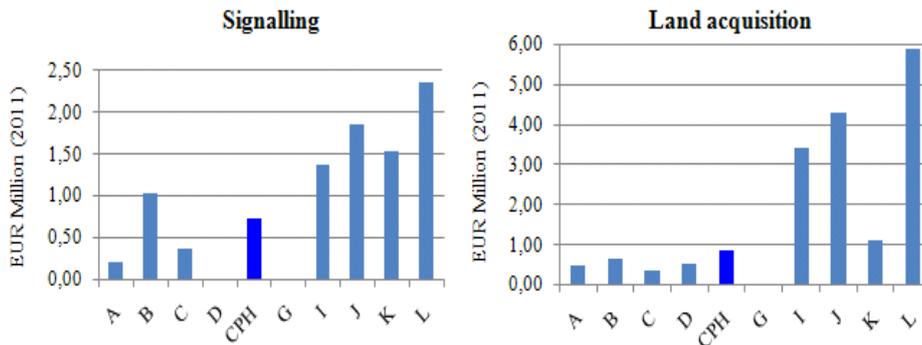

Figure 9: Cost discipline comparison of selected projects (2011)

Projects "I", "J" and "K" are equipped with ERTMS Level 2 for the whole length of the projects, therefore it brought additional costs to the total project investment, these projects were pioneers in Europe introducing new signaling system on their networks. As it was mentioned in the Steer Davies Gleave report [9], the cost of land differ from country to country, therefore these cannot be comparable, but they influence the cost values on the Figure 7.

5.2 Second benchmarking level

Further investigation and cost breakdowns were based on answers received from our questionnaire. Selected projects provided sufficient information for further analysis, although in some cases breakdowns were not possible because the data supplied was insufficient for a particular comparison; e.g. the Dutch project "Hanzelijn" could not provide data for some cost positions because they have signed design-and-build contracts for different project parts and therefore many items for railway technology and civil works were merged together in one contract. Therefore it was difficult to split them up and provide us the data. The Belgian railway infrastructure manager Infrabel could only supply us with a distribution per main disciplines after 2005, because before 2005 there was one common railway organization, while after was performed vertical separation of main organization and all costs are separated between these two organizations.

All the participants tried to match the cost distribution model of Copenhagen-Ringsted project (shown on the Figure 2) that we provided them through the questionnaire. Although the received results were not straight-forward comparable in some disciplines, since the different approach in calculation was used by project representatives. Considering received values there were decided to focus on comparison of main cost drivers, such as unit costs of tunnel/viaduct construction and railway components.

In the cost discipline "*Railway track construction*" the Copenhagen-Ringsted project budget includes costs for railway superstructure, switches, ballast and installation.
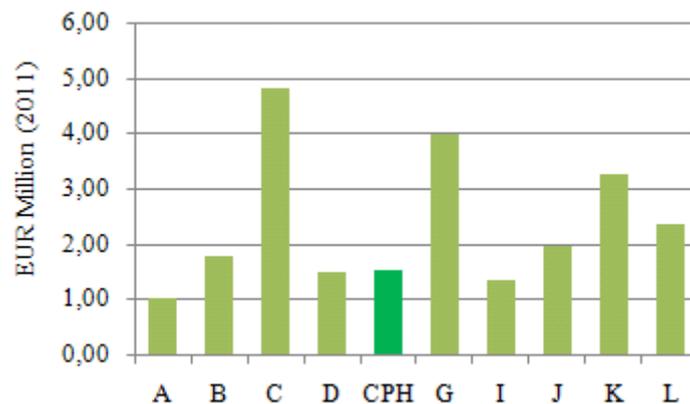

Figure 10: Cost values for discipline "Railway track construction"
(average value EUR 2.35 Million/km)

The project "C" result was 3 times expensive, as it is shown on the Figure 10. When the responsible person was asked for explanation of so high value, the answer was that in this discipline they have also included the costs for administration and consultancy, therefore this result cannot be straight comparable to other projects in this discipline. Administration and consultancy costs usually are accounted as 15 % of total costs, therefore this value is under investigation. The same is true for the project "G". The project "K" value is also higher than average and we assume that it is because of the upgrade of existing double track alignment and expansion to the four-track railway. The

other projects are laying below the average costs and have more-or-less similar values.

In discipline "*Earth works*" for Copenhagen-Ringsted project all costs are related to earth excavation, its transportation to depots, cleaning of contaminated soil, etc.
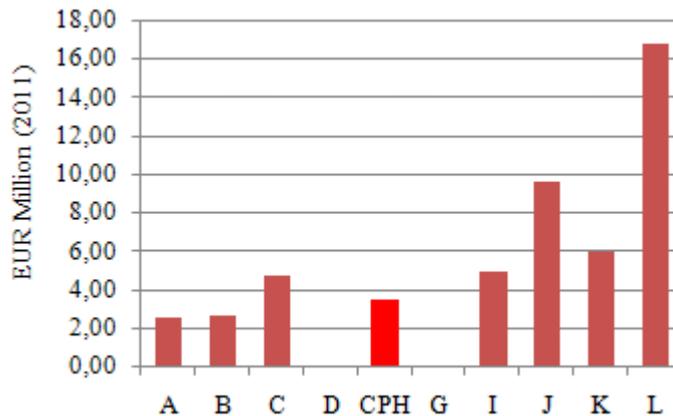

Figure 11: Cost values for discipline "Earth works" (average value EUR 6.30 Million/km)

On the Figure 11 projects "J" and "L" have higher values among others, this is explained by the local legislation within one country they are from. In order to construct the project within the plan, infrastructure manager had to fulfil the requirements set by local municipalities and authorities, therefore for the project "L" was obligated to construct the motorway neighbouring to planned railway line and also other additional constructions. Therefore these costs are not extracted from the total project budget, as it was found during analysis of received information. The costs for projects "D" and "G" were not taking into this comparison because of lack of data as it was mention before.

Copenhagen-Ringsted value is close to the projects "A" and "B" values, although they are cheaper in total comparison.

Whereas on the Figure 12 is presented discipline "*Civil works*", where all projects are almost in the same cost range, excluding project "C" which value is quite low and we are still waiting for explanation from the responsible person and project "L", which consists of construction of motorway and therefore it influences the total cost value.
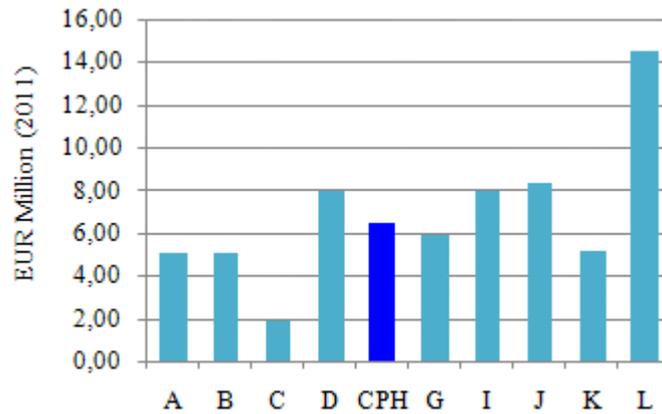
Figure 12: Cost values for discipline "Civil works" (average value EUR 6.82 Million/km)

It is important to notice that projects "A","B", "C" and "D" have lower total costs than Copenhagen-Ringsted project (as it is shown on the Figure 7), although there were no significant correlation in the cost results by observed cost disciplines between those projects. However the other projects costs are higher than the Danish project with the same dependency as it is seen on the Figure 7.

The illustrated comparison did not provide the full answer why projects from the left-hand side are cheaper in the total cost per kilometre comparison. Therefore, we decided to go deeper into investigation of unit costs, i.e. the costs for railway superstructure, tunnel construction costs, bridge construction costs, etc.

5.3 Third benchmarking level

The third level consists of comparison of main unit prices, i.e. costs per railway superstructure, switches, road and rail bridges, tunnels, etc. The data collection process is still on-going and data presented in this paper has preliminary values.

The values of projects "A" and "I" are shown in the Table 3: The review on unit costs per major elements.

The costs per major structures are different because of the structure sizes, used materials and contractors. Although, project "A" and Copenhagen-Ringsted have more-or-less similar values and it might be explained by the geographical location of both projects in the Northern Europe, where almost the same suppliers and contractors are used, that is why the price level is also in the same range. Whereas the "I" project has cheaper values for bridge construction and its represents the Southern Europe in our comparison, proofing again that labour cost values and material costs (e.g. they have their local concrete factories) are cheaper there. Questionnaire answers from both projects show, that on these projects only local companies were involved into construction processes.

Table 3: The review on unit costs per major elements

	CPH-RG	A	I
	EUR/m2	EUR/m2	EUR/m2
1. Road bridge (beam)			
Big 900-2580 m2	2000	3000	1800-2400
Railroad beam bridge	x	5000	900-1500
2. Frame bridge for undergoing path or waterflow			
50-200 m^2	4000	4000	x
3. Frame bridge for undergoing road			
100-300 m^2	3500	3500	x
4. Path bridge above the railway			
50-500 m^2	2000	3400	x
	EUR/m	EUR/m	EUR/m
5. Tunnel			
with earth cover	x	15500-16000	24000-30000
	EUR	EUR	EUR
6. Switches			
New switch 1:14 (or 1:15)	176000	147000	130000
New switch 1:26,5 (or 1:27.5)	303000	227000	305000

6 Discussion

The paper describes the method of possible cost saving for the case study – "The New line Copenhagen-Ringsted" project, as well as for any other transport projects by using benchmarking tool. The method consists of creation a database with comparable projects, furthermore comparing those to the case project in terms of the total costs per kilometre and thus its further breakdown by different disciplines and unit costs. It helps to find the position of studied project among the others and later on define the areas that influence the high cost values in relation to the cheaper projects. Normally, these costs are depended on labour costs and complexity of main civil structures.

The results of different comparison levels show that the position of the Copenhagen-Ringsted project is below the average value of the total cost per kilometre of selected projects, however, there are still few projects in front of it with lower costs and best practices in the high-speed railway construction in Europe. Those projects represent the countries with developed high-speed rail systems and experience, therefore these factors also influence the total costs of projects.

The rough values of costs for relevant disciplines (i.e. track, earth and civil construction) show that there is no significant difference between Copenhagen-Ringsted values and the values of projects with lower total costs, although those projects with

higher total costs end up with higher results in the single discipline comparisons. Altogether the range of cost values has a smooth spread in each particular comparison, excluding values in the land acquisition and signalling disciplines.

Although some project values differ significantly and their values are 3-4 times higher than others. Firstly, this may be explained by different components being included in a particular discipline by responsible persons, because the cost calculation and distribution by main disciplines depends on the approach used in a particular company. The budgeting model of Copenhagen-Ringsted project was provided as a template for all participants. However they already had their own models of cost distribution and sometimes it was difficult to adjust all cost values to the same type. For example, in the Netherlands they divided their project into several parts and performed it through design-and-build contracts, which finally made it not possible to extract the cost data to match Copenhagen-Ringsted model.

Secondly, such factors as complexity in civil works in each project, country's technical and construction standards, cooperation with local authorities – all this may influence the final values presented in this paper. In some projects higher construction costs are also explained by the local legislations. For example, in Italy cooperation with local municipalities takes time, efforts and additional costs. Italian railway network from Turin to Napoli came out 3 times expensive than it was planned at the beginning. The reason is in change of railway line location in some places, construction of architectural bridges, roads and other infrastructure elements – all this was requested by local stakeholders in order to allow to build the line on their territories.

The investigation of unit costs per major elements is still under analysis and data collection, therefore in this paper only few values of bridge and tunnel construction were presented. E.g. in the Netherlands contractor is responsible for purchase of construction materials and railway elements and its prices is included into the contract price, hence it is not possible to take the Dutch values to our comparison of unit costs. Although it was concluded that the geographical location of the projects means that the range of unit costs are very similar, because of the use of the same companies and material presented in the common construction market.

The research is still ongoing and we are sure the final results of the study will provide more outputs to answer the posted question of this paper, whether the cost benchmarking can help to reduce the costs of a particular project. The preliminary results of this paper provide an additional knowledge in cost positions of other projects and further detailed investigation of the cost performance of cheaper projects will provide more information about possible ways to reduce the budget of the case study project.

7   Preliminary recommendations

Received results from the second benchmarking level show that the countries with developed high-speed railway network have lower cost results. It is vital to observe their experience in details and apply their approach to the new projects, e.g. contracting procedures, technology and materials, etc. Although there are some exceptions, mentioning Italian HSL experience with final costs of Turin-Napoli network 3 times expensive that it was planned initially. However, Southern Europe countries have longer experience in high-speed rail operations and lower costs per materials and labor. The construction companies, e.g. from Spain and Italy, are well known in international construction marked with many large reference projects.

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