REAL OPTIONS APPROACH FOR EVALUATING AN INTERNET SERVICE ON TRAINS ROLLOUT

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Abstract

Internet on the train has gained more and more interest in the railway sector in the last few years. The attraction of potential new rail customers is mostly envisaged by the railway companies, and in this way Internet services to train passengers is seen as a major opportunity. First we discuss our generic business model to evaluate and compare diverse technical scenarios, for guaranteeing a continuous network connection. To obtain real figures, our model is applied on the Belgian railway network, and we have performed a general cost/benefit analysis for the different technical scenarios. A sensitivity analysis shows then the most influencing parameters in our model. Based on this information we have created a real options calculation method for optimizing the rollout scheme, as this was originally kept fixed. By introducing certain flexibility in the rollout schemes, the viability of an Internet on the train rollout can be seriously optimized.

Keywords: Internet services on trains, Real options, Business model

Introduction

Internet on the train has gained a lot of interest in the railway sector over the last few years, especially in Europe [1]. Most railway operators are seeing this as an opportunity for long (high speed) train lines to compete with short range airline services. When train passengers have to travel for several hours, they might spend their time more useful for either work or pleasure purposes, thanks to their Internet connection. An example of such a service is currently rolled out by Thalys [2], a high speed train operator connecting Amsterdam, Brussels, Paris and Koln.

Complementary to this long train line scenario, this paper focuses on a dense railway network, and on the advantages of offering an Internet service to commuting passengers. Every day millions of people are spending on average about 45 minutes on a train while travelling to and from work. This is a huge customer base, deprived of broadband access connectivity. The key question that needs to be answered is whether a viable business model exists for offering an Internet onboard service.

The main issue in offering such services is to set up a seamless network connection from the train to the local environment. Several technological solutions are currently deployed, ranging from using available mobile networks, renting satellite connections or building dedicated wireless data networks along the tracks. The choice will depend on the train type (such as long-distance and commuter trains), the environment trough which the train travels (such as cities, hilly areas, tunnels, etc.) and the offered services (e.g. best effort, real-time, high-priority, etc). To offer a cost-efficient and reliable Internet services on the train, current deployments often use a combination of the mentioned technologies [3]

In section 2, we present our generic business model. The most important building blocks, such as the technical scenarios and cost/benefit analysis are examined into more detail. Section 3 performs a real options analysis to introduce flexibility in the rollout scheme for an Internet on the train service. This analysis starts with a thorough sensitivity analysis which predicts a general forecast of the outcome and also indicates the most influencing parameters. Based on these results, we present the calculation method and results for optimizing the rollout scheme, making use of a real options formulation. We end our paper with some conclusions in section 4.

Generic business model

Our generic model is created within the IBBT Tr@ins (Train IP Network services) project. This project focuses on the development of an integrated solution for broadband access for train passengers by making use of several wireless technologies [4]. Within this project, we analyse several technical scenarios suited for offering a broadband Internet service on the train, for passengers as well as railway personnel. The purpose is to evaluate these scenarios, taking into account technical parameters, user study information and cost/benefit figures. A first version of the model was presented in [5].

The model consists of three major blocks, which are further split up in smaller interconnected building blocks presented in Figure 1. The first major block contains the passenger forecasting model, as well as the train relation rollout schemes and the calculation of the potential customer base. The second major block contains the steps for assigning an appropriate technology to the different train tracks. Seven technical scenarios are defined based on three main technology categories. When all previous information is gathered, we can work out as final major block a cost/benefit model for each scenario. The output of our business model is the comparison of the different scenarios, taking into account several fluctuating parameters such as user adoption, bandwidth variations, etc.

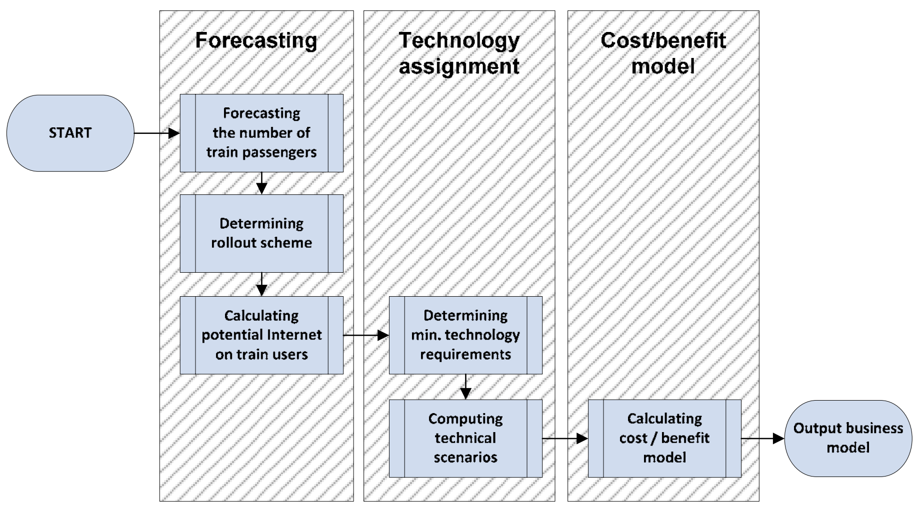

Figure 1: Generic business model

Forecasting

The basic input required for such business cases is a right estimation of the number of train passengers distributed over the railway network, and detailed per railway track and train relation. We define a railway track as the (physical) interconnection between two successive railway stations, and a train relation as a fixed train connection between two end-stations, mostly according to a predefined timetable. As the required information cannot be retrieved from public sources, we have created a forecasting model which predicts the number of passengers on the train relations between each station. To obtain concrete figures, we have applied our model on the Belgian railway network, which is one of the densest networks in the world [6]. All intercity (IC) and interregional (IR) train relations have been put into the model including several parameter values (track lengths, stations, type of trains, number of carriages, etc). Based on this input, we can calculate the number of train passengers per track for each specific train relation. By combining these figures for the train relations equipped with an Internet service, and with results from a market research study that was performed within the project, we can estimate the number of first and second class Internet on the train users. The distinction between both classes is important as we take into account a modal switch from second to first clas. This can be seen as an important opportunity for the train operator as revenue factor.

We assume a gradual rollout (spread over five years, i.e. from 2008 to 2012) of the Internet service on the train on the Belgian IC and IR train relations. An important factor to encourage the user adoption is that passengers are assured an Internet service is available on each train of an equipped relation. In this way, we assume that all trains per relation are equipped at once. The rollout sequence is based on the number of railway passengers per relation, so the busiest relations are deployed first.

The user adoption for the Internet on train service is modelled by using a Gompertz curve [7]. This model forms an asymmetric S-shaped curve, with the adoption slowing down as it progresses. More precisely, the Gompertz curve assumes that the period of increasing growth of adoption is shorter than the period in which this growth is decreasing and in which it is adjusting to its saturation level (1).

$$S(t) = m \cdot e^{-e^{-b(t-a)}} \qquad (1)$$

Where:

m	=	maximum market potential
a	=	inflection point, which occurs at an adoption of 37%
b	=	rate of adoption
t	=	time

As not all train lines are rolled out in the same year, we have decreased the infliction point parameter *a* per rollout year. When more trains are equipped for offering the service, a quicker adoption is assumed due to passenger acquaintance with the service. As maximum market potential, we suppose an adoption of 15% for first class passengers and 7.5% for second class passengers. The adoption curves for first class passengers are presented in Figure 2 which clearly illustrates the much faster user adoption for a rollout in 2012 compared to e.g. 2008.

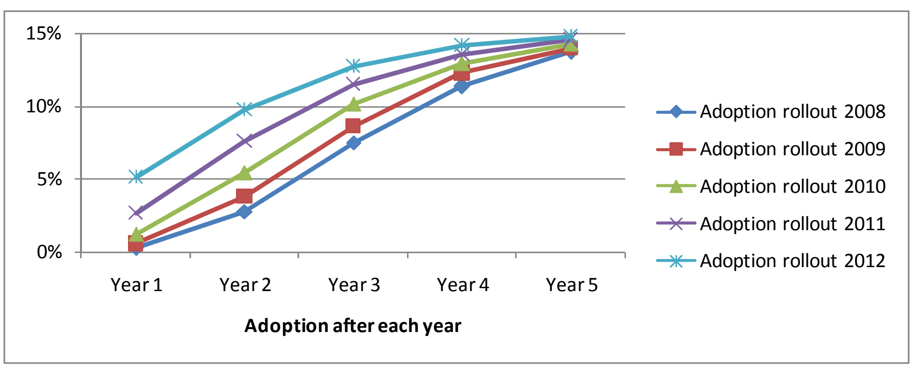

Figure 2: Gompertz adoption curves for first class passengers

Technology assignment

As mentioned before several technologies can be used for setting up an outdoor connection from the train to the local environment. Three categories can be defined: mobile networks, wireless data networks and satellite networks. An overview is given in Table 1.

Mobile network technologies use a cellular approach to provide radio coverage over a wide area (e.g. nationwide coverage). These networks are most commonly rolled out by the mobile telecom operators, and are successors of the well-known GSM technology. The bandwidth varies from ca. 160 kbps for GPRS up to even 14 Mbps for HSDPA. The attainable bandwidth however, typically decreases with an increasing user speed, and in this way a bandwidth of ca. 900 kbps is more realistic for HSDPA. The maximum train speed for using these technologies can reach up to 250 km/h. The primary requirements are good coverage and also high mobility, rather than high bandwidth due to the fact that telecom operators' customers are mainly concerned about mobile telephony than data requests.

An alternative to the mobile networks operated by telecom operators are wireless data networks. To cover a certain rail track, new base stations have to be installed along the railway trakcs, and in this way, such a network is often referred to as a dedicated trackside network. They can use directional antennas to cover a large track distance with high bandwidth. Examples of such technologies are WiFi, WiMAX and Flash-OFDM. WiFi access points are used today in stations for hotspot services. Their disadvantage is the limited coverage (300 m) compared to the larger coverage ranges for WiMAX (up to 6 km) and Flash-OFDM (up to 18 km). Theoretical bandwidths of ca. 50 Mbps can be reached with these technologies. At normal to high train speed we can assume a bandwidth in the order of 2 to 5 Mbps. Flash-OFDM has the advantage that it can cover train speeds up to 500 km/h which is not the case for the other two technologies. The Mobile WiMAX standard supports user speeds of 120 km/h, and the WiFi standard does not support fast mobility. For both WiMAX and WiFi however, there exist several proprietary solutions implementing a fast handover to reconnect from one base station to the next one.

Satellite networks are the third category of communication links that can be used. Most satellites have a large footprint covering complete rail networks, therefore making this technology interesting for covering large train networks without the disadvantages of handovers. High data rates can be reached with one satellite for the duration of a trip, for all trains. The major drawbacks are a strict line-of-sight (LoS) requirement, which can be a problem in dense urban areas and hilly surroundings, and a high end-to-end delay (at least 500 ms for a connection from the train to the satellite and back to the ground station, and vice versa). To cover the unreachable areas, a gap filler technology is needed, e.g. delivered either by a repeater or by another network belonging to one of the above two categories.

Table 1: Technology comparison [5]

Category	Mobile network	Wireless data network	Satellite network
Bandwidth	Low – high	Very high	High
Current coverage	Full coverage (except for most recent standards)	Limited coverage (new networks needed)	International (but Line-of-Sight required)
Maximum train speed	High (Up to 250 km/h)	Low – high	Very high (Up to 500 km/h)
Technologies	GPRS / UMTS / HSDPA	WiFi / WiMAX / Flash-OFDM	DVB-S / DVB-S2 / DVB-RCS

For offering a seamless network connection and/or high quality of service, a combination of technologies is usually required. We have defined seven technical cases that cover most of the commonly used network combinations (Figure 3).

Case 1 only makes use of the currently available mobile networks such as UMTS or HSDPA. The main problem is concerned with bandwidth limitations as e.g. a UMTS channel has a maximum downlink of 384 kbps. Supposing that UMTS is used as outdoor network connection, then only 15 people (25 kbps downlink per user) can set up a connection per UMTS cell. To solve this problem, we have implemented some incremental rollout scenarios combining mobile and wireless data networks. Case 2 starts with the currently available mobile networks as first option, but gradually switches over to wireless data networks where bandwidth limits are exceeded. For some heavily used tracks (e.g. between large cities), this transition will happen very quickly. Therefore in case 3 we have defined some pre-installed tracks that will be equipped with a wireless data network from the beginning. In this case data costs for mobile networks can be saved from the beginning. Case 4 is a variant of the third case in which wireless data network base stations are placed in each station where trains, offering the Internet service, are passing (cf. hotspot services in train stations [8]). On the remaining parts of the track for case 3 and 4, technology is determined by the required bandwidth (cf. case 2). A final step is a complete rollout of a wireless data network along each railway track from the beginning (case 5). Case 6 and 7 are making use of a satellite network. Case 6 considers a one-way satellite connection for the downlink connection, and mobile networks for the uplink connection as well as for covering the gaps in areas with no LoS. Case 7 makes use of a two-way satellite connection, thus for downlink as well as uplink, and mobile networks are used again as gap filler technology.

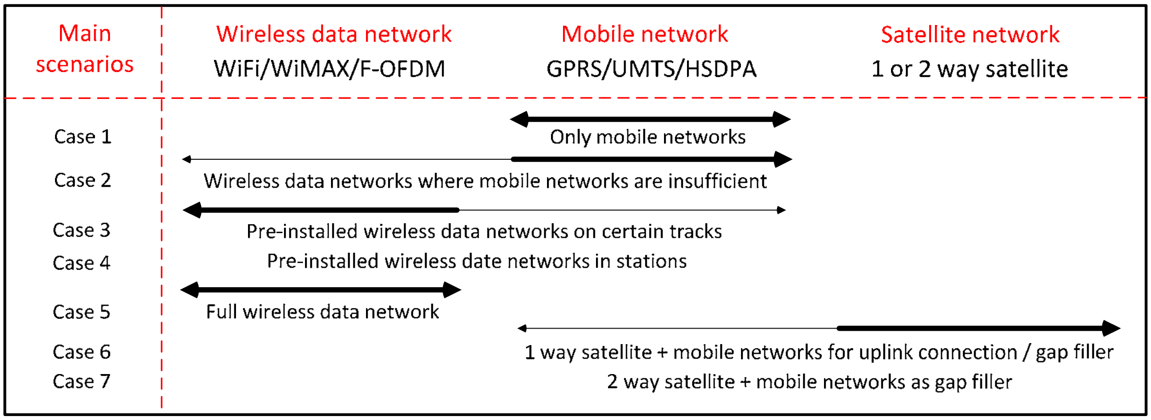

Figure 3: Seven technical cases based on three main technology categories

We have presumed in our model that each user pays for a certain guaranteed bandwidth connection. Due to the fact that not all passengers simultaneously use their connection at full bandwidth, a multiplexing factor is applied. In our analysis, we have assumed a dedicated bandwidth of 30 kbps downlink (7.5 kbps uplink) which roughly equals to a user experience of 1 Mbps downlink (256 kbps uplink). This experience is comparable to a fixed broadband Internet connection at home. Besides, to illustrate the impact of the offered bit rate, some results are shown with a varying bit rate between 5 and 55 kbps downlink (Figure 4 further on in this paper).

For each case, the appropriate technology is based on the number of Internet users per train. We can deduce the number of kilometers of track covered with wireless data networks, thus the number of base stations required, and the bandwidths consumed for each technology (mobile data traffic per train, number of satellite links serving all equipped trains).

Cost/benefit analysis

The cost analysis is split up in capital (CapEx) and operational expenses (OpEx) for each technical case. CapEx consists of two major parts: train equipment and network equipment. The first part contains the network equipment for the master and slave carriages. The master carriage contains the outdoor antenna as well as the rack with network connection modems for monitoring and coordinating the onboard network. Slave carriages are only equipped with an onboard WiFi network for the indoor network connection to the passengers. A normal train consists of a locomotive, one master carriage and multiple slave carriages. In case “units” (i.e. a fixed combination of carriages) are envisaged, the locomotive carriage is considered as master. Multiple units can be combined into one train. In this case, all units will separately connect to the outdoor network via their outdoor link. Typically, after five years the antennas are replaced. Investing in satellite antennas is more expensive than in mobile or wireless data antennas due to more moving parts (pointing and tracking components).

Network related CapEx contains costs for rolling out a dedicated wireless data network, as well as costs for the network operation center (NOC), which monitors all trains and data traffic. The costs for the first category include acquiring sites for poles, base station equipment, backhaul links and core equipment. We assume that a certain amount (fixed at 75%) of the poles along the tracks, which are currently deployed for the dedicated GSM-R network that is used for train and track management systems, can be rented from the railway infrastructure owner [9].

The operational costs (OpEx) contain the yearly returning costs. Sales, billing, marketing and helpdesk are required for offering the service independent of the proposed technology. Maintenance and repair for train equipment and NOC are a percentage of the related CapEx costs. Network planning and operational costs depend on the technical scenarios and the combination of technologies. A critical OpEx cost is bandwidth consumption. Wireless data networks are directly connected to a fiber network along the tracks or have backhaul connections between antennas, which makes them relatively independent of consumed bandwidth. Mobile data traffic is calculated per train (several mobile data SIM cards can be used in parallel with different mobile operators) and is very expensive, certainly when subscription limits per SIM card are exceeded. Satellite link capacity is dimensioned on peak moments, thus leading to an overcapacity and inefficient usage in non-peak moments.

Two revenue schemes are proposed in our model. The first consists of a full paying service for every user, and in the second scheme, first class users get free Internet access. The purpose of the second scheme is to gain extra revenues from a higher modal switch from second to first class (an increase from 1% to 3%). For the analysis in this paper, we only focus on the second scheme, as this is the most beneficial one considering the assumed adoption, revenues and costs. A split up is made between subscriptions and prepaid cards, taking into account a larger service usage of the first category of users. Finally, the price is related to the offered bandwidth: more must be paid for a faster Internet connection. We have added a penalty factor (discount on the tariff) in case the promised bandwidth could not be delivered in the technical scenarios. This only happens when mobile networks are considered for downlink or uplink (case 1, 6 and 7).

Output of the business model

As already mentioned, we assume a five year rollout for the whole network. All technical cases are evaluated and compared for a 10-year analysis (2008 to 2017) using the net present value (NPV) method (assuming a discount rate of 15%). In Figure 4 the results of a basic rollout scenario are shown for a varying bandwidth offered to the customers. For the cases where UMTS is used as common technology, the NPV results are deteriorating when bandwidth per user increases. This can be explained by the fact that costs for data traffic over mobile networks are very expensive and bandwidth over this medium is limited, thus leading to fewer revenues due to the penalty factor. The full WiMAX case is not viable due to the less interesting tracks that need to be covered. Therefore the incremental scenarios (case 2, 3 and 4) have a large advantage as upgrades of the network occur based on bandwidth demand. The satellite scenarios (case 6 and 7) are liable to large train equipment and network (satellite link and UMTS data) costs.

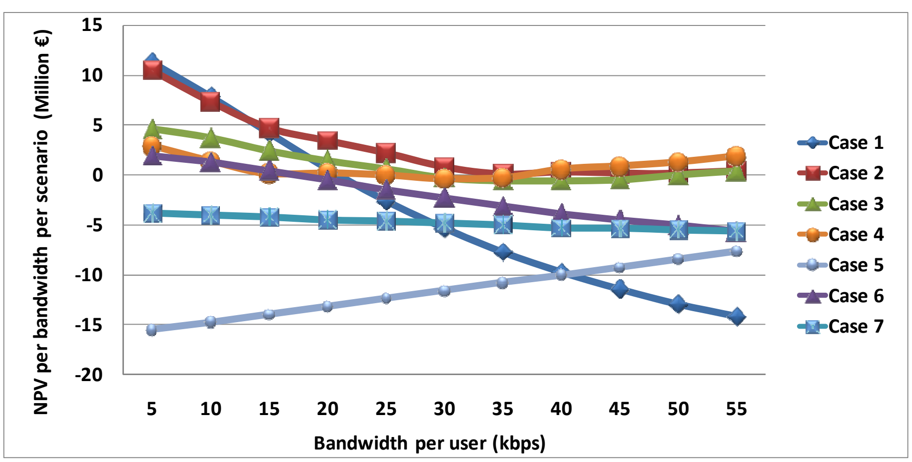

Figure 4: NPV results for different bandwidths per user, and a basic rollout scenario.

The results are calculated based on a fixed rollout schedule. We have analyzed the effect of diverse rollout schemes on the overall result. In the next paragraph, we further elaborate on this study by using a real options analysis for optimizing the rollout of the train relations.

Real options analysis

So far, we have assumed a static model with a fixed rollout scheme and speed, based on the number of passengers per train relation. However, in a real deployment, the rollout strategy will typically be evaluated during the project and adapted to the market situation. To introduce this flexibility in the rollout of our Internet on the train model, we have applied some principle from real options theory, which are then validated by simulations.

First of all, we have performed a sensitivity analysis on the static rollout model by varying the input parameters. These sensitivity results lead to a forecast of the general outcome (e.g. NPV results) of the project. In a second part, we have performed a real options analysis by introducing a flexible rollout scheme based on the outcome of the project. The flexible rollout strategy takes the general outcome of the first sensitivity analysis into account to define the most-suited scheme.

Sensitivity analysis

As our model contains a lot of uncertain input parameters, we have performed a sensitivity analysis based on Monte Carlo simulations by using the Crystal Ball tool [10]. We have run 25,000 trials with varying input parameters, and as result, we get a good idea of all possible outcomes for the different scenarios. Table 2 lists the considered parameters together with the probability distributions according to which the parameters are varied. For the cost related parameters, we have defined triangular distributions, except for bandwidth per user and the number of SIM cards per train, where we have assumed a discrete uniform distribution. As most costs are retrieved from business partners within the Tr@ins project, we have a relative realistic view of them. For the user adoption parameters we have also used triangular distributions. We know from previous analyses that using the Gaussian distribution causes a too large influence of these parameters on the overall result. Revenue and modal switch parameters are presumed to be uniformly distributed. We have also taken into account an inverse correlation between the tariff per hour and the first and second class adoption, respectively -0.25 and -0.75. This reflects that the attraction of second class passengers will probably strongly depend on the service tariff.

Table 2: Sensitivity parameters

Parameters	Distribution	Average	Minimum	Maximum
User adoption				
First class adoption	Triangular	15%	10%	20%
Second class adoption	Triangular	7.5%	5%	10%
Modal switch	Triangular	3%	1%	5%
Revenues				
Tariff per hour	Uniform	3.5 €	3.0 €	4.0 €
Tariff modal switch	Uniform	5 €	4.5 €	5.5 €
Train equipment costs				
WiMAX or mobile outdoor antenna	Triangular	1,500 €	1,350 €	1,650 €
Satellite outdoor antenna	Triangular	30,000 €	27,000 €	33,000 €
WiMAX or mobile network equipment cab car	Triangular	7,500 €	6,750 €	8,250 €
Satellite network equipment cab car	Triangular	10,000 €	9,000 €	11,000 €
Slave carriage equipment	Triangular	5,000 €	4,500 €	5,500 €
WiMAX network equipment costs				
WiMAX antenna equipment	Triangular	15,000 €	13,500 €	16,500 €
WiMAX sector unit	Triangular	6,000 €	5,400 €	6,600 €
WiMAX backhaul (CapEx)	Triangular	5,000 €	4,500 €	5,500 €
WiMAX core equipment	Triangular	400,000 €	360,000 €	440,000 €
WiMAX / Mobile network operation centre (NOC)	Triangular	150,000 €	135,000 €	165,000 €
NOC Backbone Connection + VAS	Triangular	85,000 €	76,500 €	93,500 €
Lease and maintenance own sites	Triangular	2,500 €	2,250 €	2,750 €
Cost shared sites	Triangular	5,000 €	4,500 €	5,500 €

WiMAX backhaul (OpEx)	Triangular	3,000 €	2,700 €	3,300 €
WiMAX spectrum license	Triangular	50,000 €	45,000 €	55,000 €
Leasing percentage poles	Triangular	75%	60%	90%
Satellite equipment costs				
Satellite network operation centre (NOC)	Triangular	300,000 €	270,000 €	330,000 €
Satellite hub antenna rent	Triangular	90,000 €	81,000 €	99,000 €
Network connection costs				
Cellular bandwidth cost	Triangular	42 €	38 €	46 €
Satellite link cost	Triangular	5,000 €	4,500 €	5,500 €
Number of SIM cards per train	Discrete uniform	2	1	4
Bandwidth per user (kbps)	Discrete uniform	30	5	55
General operational costs				
Marketing	Triangular	10,000 €	9,000 €	11,000 €

Figure 5 shows the forecast of the NPV after 10 years obtained by the sensitivity analysis for case 1, in which we only assume the use of mobile networks for the outdoor connection. Note that the depicted frequencies represent an NPV interval of one million €. In 33.19% of the trials, we obtain a positive result. The distribution is lopsided on the negative side. This can be explained by the penalty factor that is applied when bandwidth demand cannot be guaranteed due to technological limitations. Case 2 (Figure 6), in which an incremental rollout of a wireless data network is assumed, shows the best results of all cases (positive case in 72.24% of the trials). Case 5 (full dedicated network) barely shows a positive result (only 0.17% of the trials), which is also the case for the two-way satellite case (4.66%).

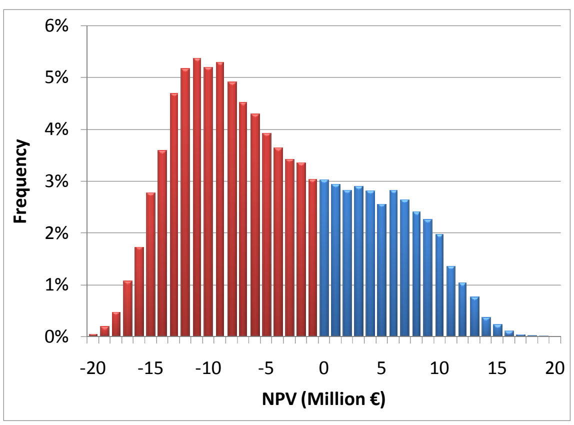

Figure 5: NPV sensitivity result case 1

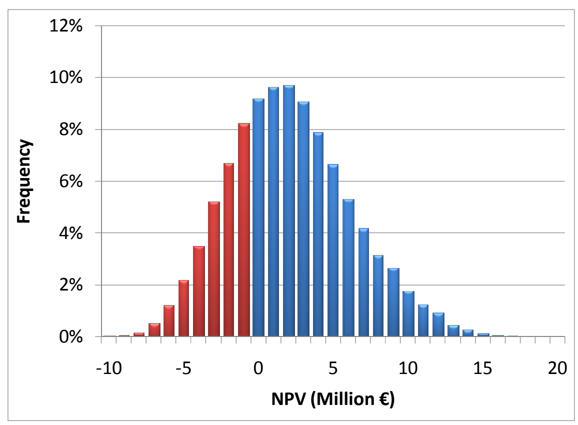

Figure 6: NPV sensitivity result case 2

When we take a look at the most decisive parameters per case (Figure 7), we see that bandwidth per user has a very negative influence on cases where UMTS is used as primary technology (-94% and -51% on NPV after 10 years for respectively case 1 and 2). The second most influencing parameter is the second class adoption. In Belgium, 97% [11] of all train passengers are seated in second class, meaning that adoption for Internet services for this group will be crucial to the overall viability of the business cases. This can be seen for cases 2, 5 and 7 (respectively 32%, 51% and 70%). Other parameters that are decisive in all cases are the number of mobile SIM cards per train, the number of modal switch customers from first to second class and the tariff per hour. What is very interesting is that almost no cost parameters are that significant in all models, except for a negative influence of the satellite outdoor antenna cost for case 7 (about 5 times more expensive than wireless data or mobile outdoor antennas) and a positive influence of an increase of the number of leased poles for the wireless data networks (more leasing means less investing in new poles).

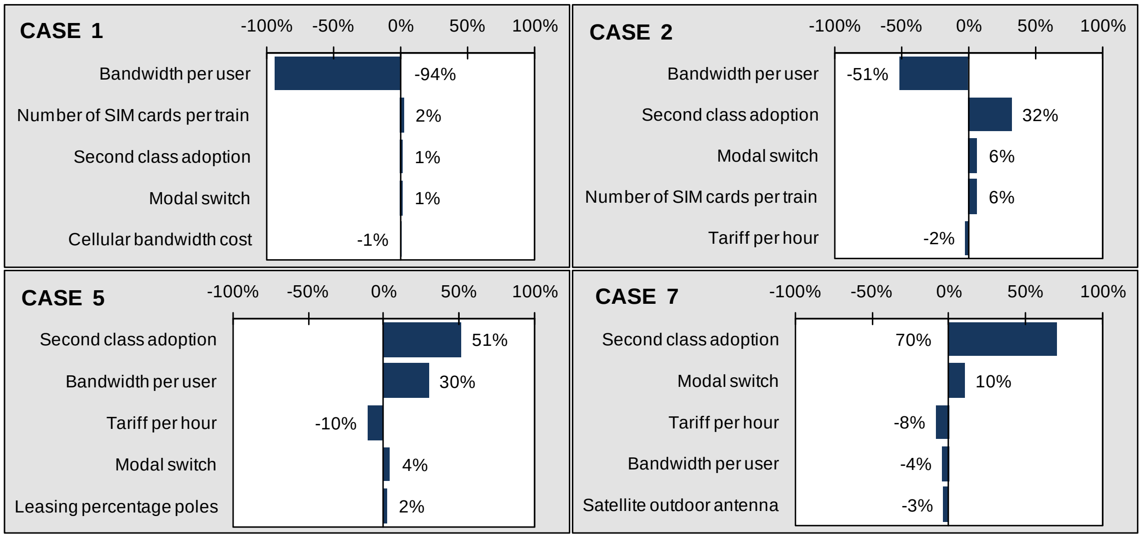

Figure 7: Sensitivity results for case 1, 2, 5 & 7

Real options scenarios

In the previous section, we have analysed and compared various technological solutions for offering Internet services on trains. A weakness in the model is the fixed rollout scheme that is currently taken into account. To optimize the outcome of the model, we have introduced real options for optimizing the rollout schemes, depending on the results from previous rollout years. Suppose that the adoption stays below the expected forecast, a slower rollout scheme can be applied. As investments in telecom networks can be risky and might involve enormous costs, these options should be considered.

A real options analysis delivers an appropriate framework to introduce certain flexibility in our rollout model, which reflects the strategy of an active management. By the time of a new investment phase, the market situation is already more clear, so that a well-advised decision can be taken for the progress of the project (whether or not to exercise the real option). The introduction of flexibility, will very often involve an extra cost at the beginning of the project. To make it possible that several options can be exercised in the next phases, some measures have to be taken from the beginning. Examples are the purchase of licenses to cover all possible scenarios, installation schedules for the trains depending on the amount of relations to be rolled out, etc.

Various real option types can be classified according to a so-called 7S-framework: invest/growth options (Scale up, Switch up, Scope up), defer/learn options (Study) and disinvest/shrink options (Scale down, Switch down, Scope down) [12]. For the deployment of a new telecom network, the scale up type real options is used since the network will be extended dependent on future market developments. This option is valuable since the operator need not currently commit to undertaking the future investment, thereby limiting downside risks. Note that several option valuation techniques are distinguished in the literature. In this paper we only consider valuation through simulation, which is the most intuitive technique.

The rollout scheme will be adapted at discrete points in time (each year in this analysis) by increasing or decreasing the planned rollout speed. Several parameters can be chosen as decision variable to determine the rollout in the next phase. We roughly distinguish two groups: diverse economic evaluation parameters are a good choice (e.g. NPV, free cash flow, payback period, etc), or we can focus on some uncertain input parameters (e.g. based on the sensitivity results depicted on Figure 7). As the evaluation of the project in the previous sections is mainly based on an NPV analysis, a natural decision variable is the NPV value at the end of each year. If the NPV follows the expected trend, the normal rollout speed as defined in the static rollout model is followed. Otherwise a faster or slower rollout is performed. We have set up a simulation scheme where we define five different rollout speeds for each next phase (i.e. a decision tree with five branches in each node or decision point). The choice of the most-suited option is determined by the normal distributions for the forecasted NPVs (cf. Figure 6) of which we use both the mean value μ_{NPV} and the standard deviation σ_{NPV}. A normal rollout is applied if: $\mu_{NPV} - \sigma_{NPV} < NPV < \mu_{NPV} + \sigma_{NPV}$. In the worst case (i.e. $NPV < \mu_{NPV} - 3\ \sigma_{NPV}$) there is only a very limited rollout and in the best case (i.e. $NPV > \mu_{NPV} + 3\ \sigma_{NPV}$), the network is immediately expanded much faster than originally planned. For the remaining NPVs, two intermediate scenarios are defined. Additionally, after each year, we have analysed the NPV after 10 years for that rollout. If the 10-year NPV for the rollout until that year is lower than the 10-year NPV of the rollout until the previous year, a rollout of one step slower will be assumed than previously defined. For instance, if the NPV after 10 years for the rollout until 2009 is lower than the one for the rollout until 2008, and the proposed rollout speed is e.g. one step, then no investment will be considered in 2009. This is illustrated by the dotted lines in Figure 8 where, each year, we analyse this so-called 10-year NPV and a reduction in the rollout speed is possible. Note that the normal rollout scheme is indicated in a dark full line.

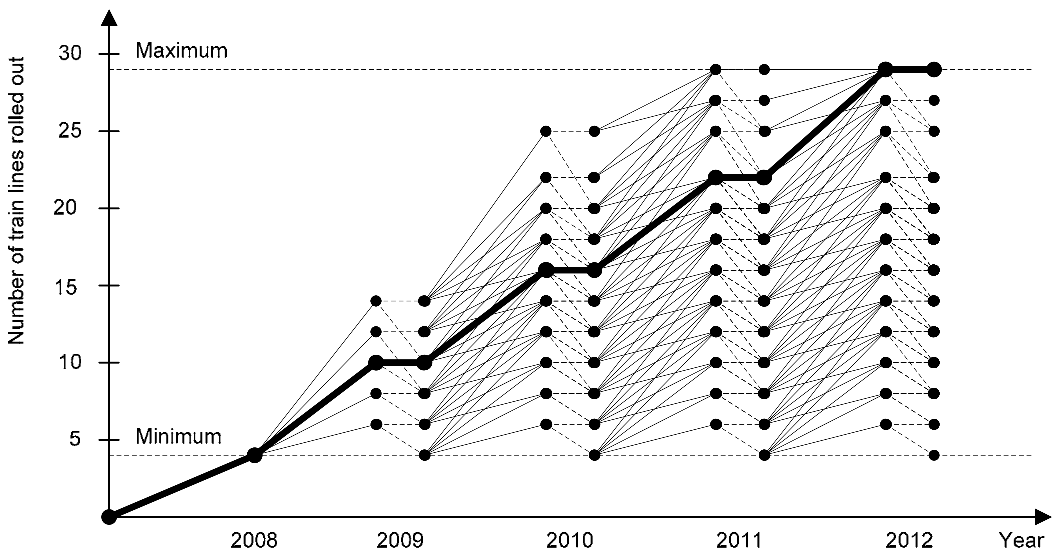

Figure 8: Real options proposed calculation method

This real options calculation method has been applied to the four most diverse technical cases, mentioned in the previous section. The final results can be found in Table 3. Figure 9 and Figure 10 show the results for the real options analysis compared to the static analysis. In the left chart of Figure 9, the NPV after 5 years is presented for case 1. A clear shift to the right is obtained, leading thus to a more positive business case. The final results (i.e. after 10 years) can be seen on the right chart where the full business case is presented. The average NPV after 10 years amounts -2,141,492 €, leading to an option value of 1,350,796 € compared to the static average. For case 5 (Figure 10), an even larger shift can be seen in the NPV results after 5 years (left chart). The option value after 10 years amounts to 985,275 €. Cases 2 and 7 show an option value of 462,672 € and 1,172,087 € respectively.

For all cases, the percentage of positive runs has increased after the real options analysis. Case 2, which considers an incremental investment in a wireless data network, shows the largest increase (77.22 % compared to 72.24% in the static analysis). The standard deviations decrease due to the fact that decisions were made depending on intermediate NPV results.

Table 3: Real options final results

	Case 1	Case 2	Case 5	Case 7
Static analysis after 10 years				
Average	-3,492,288 €	2,616,034 €	-11,812,755 €	-4,985,026 €
Standard deviation	7,947,554 €	4,119,752 €	4,239,834 €	3,025,703 €
% positive results	33.19 %	72.24 %	0.17 %	4.66 %
Real options analysis after 10 years				
Average	-2,141,492 €	3,078,706 €	-10,827,480 €	-3,812,939 €
Standard deviation	6,799,743 €	3,962,753 €	3,890,439 €	2,729,772 €
% positive results	34.32%	77.22%	0.32%	8.64%
Option value	**1,350,796 €**	**462,672 €**	**985,275 €**	**1,172,087 €**

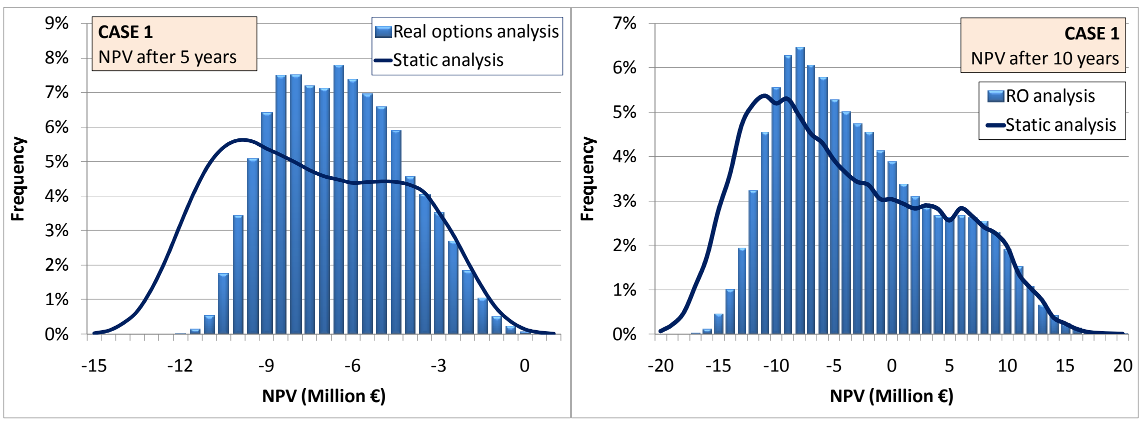

Figure 9: Real options results for case 1

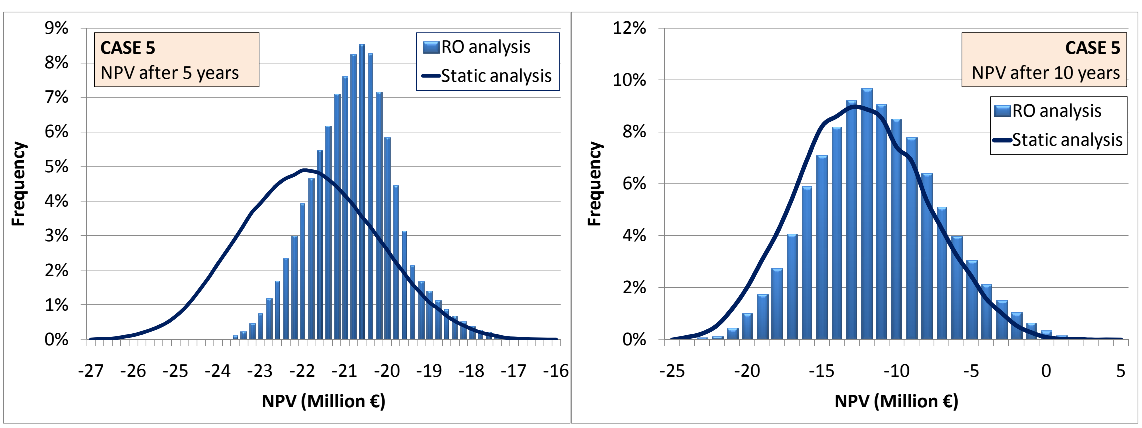

Figure 10: Real options results for case 5

Conclusions

This paper presents a generic business model for Internet services on trains, more specifically focused on dense railway networks. The Belgian railway case is used as business case for analysing the potential viability of diverse technical scenarios combining different technologies. A static business case with a fixed rollout scheme is elaborated and a detailed sensitivity analysis is exercised. As the rollout scheme and speed is crucial for the viability of the business case, we have proposed a real options calculation method to adapt the rollout speed based on the NPV results. This leads to an amelioration of the business cases, especially for case 1 (only mobile networks) and case 7 (two way satellite) with option values of respectively 1,350,796 € and 1,172,087 €. Case 2 has an increase of positive NPV outcomes up to 77.22% compared to 72.24% in the static case. Case 5, where only wireless data networks are used for covering the railway network, shows only a slight increase. This can be explained by the fact that the rollout scheme is not optimized for this scenario. In this paper, we have based our rollout scheme on the amount of passengers per train relation. If we should combine the number of passenger per train relation with the followed rail tracks, thus relating train relations that are running over the same tracks, even better results could be achieved.

Acknowledgments

This research was carried out as part of the IBBT Tr@ins project [4].

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