DELIVERABLE

D0602. FINAL CONSOLIDATED REPORT - CHAPTER 4

Related Milestone
M6.2
031312
PROJECT N°
FP6-31312
ACRONYM
URBAN TRACK
TITLE
Urban Rail Transport
PROJECT START DATE
September 1, 2006
DURATION
48 months
Subproject
SP6
Work Package
WP6.2

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Date of issue of this report
15/11/2010

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Project funded by the European Community under the SIXTH FRAMEWORK PROGRAMME PRIORITY 6 Sustainable development, global change & ecosystems
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4. LIFE CYCLE COST (LCC) CALCULATION (SP4)

This part of the projects (SP4) – developed by DI and TTK - deals with the development of a LCC model and an associated software tool. It also addresses the socio-economic cost of track construction for nearby residents and shops. It is applied to various cases presented in chapter 3, and especially to the Seville test site (chapter 3.4).

Considering that urban railway operation is characterized by the need for large initial investments and large annual budgets for maintenance/renewal activity, the systematic and controlled development of LCC strategies on a European level and their comprehensive implementation become a crucial issue for the economic sustainability of the urban railway business.

The scope and definition of the LCC include the definition of the parameters that have to be taken into account, and of the methodology to be used for determining the LCC.

4.1. OBJECTIVE

Today’s urban railway sector is imposing high demands for service quality on railway infrastructure managers. Since railway infrastructure has a long asset life, it requires both global approaches for the selection of new types of infrastructure and efficient maintenance planning to perform effectively throughout its life cycle to meet these high demands. Traditionally maintenance decisions and the choice of new types of urban railway infrastructure have been based either on past experience and expert estimations (for maintenance decisions) and mainly investment costs (for the selection of new systems).

The objective of the sub project 4 is to develop, test and provide a LCC methodology to SP1, SP2 and SP3 partners that will allow them to evaluate the innovative products and procedures developed.

The objectives of SP4 are to obtain:

- a generally acceptable LCC calculation method and software tool with definition of all important parameters involved for evaluating complete projects as well as for the evaluation of the introduction of innovative solutions into the network
- validation by use of the above LCC calculation method for the solutions at the validation test sites considered in SP3;
- support of the studies defined in the other SP with relevant LCC information;
- project target verification (25% reduction of LCC) of the proposed solutions;
- a cost/benefit analysis methodology for rail infrastructure works including socio-economic aspects.
4.2. **STRATEGY USED AND/OR A DESCRIPTION OF THE METHODS (TECHNIQUES) USED WITH THE JUSTIFICATION THEREOF**

One of the objectives of SP4 is to allow a better understanding on how leading edge track system technologies can contribute to life cycle cost optimisation, given the projects specifics.

In order to reach this goal, a set of tasks have been formulated to be carried out at different stages of this European research project. These tasks include:

1. Development of the LCC model (M24)
2. Development of a software tool (M24),
3. LCC calculations as input for SP1/SP2 (M24/M36),
4. LCC calculations for the on-site tests (pre-installation) (M36),
5. LCC calculations analyses for the on-site test (post-installation) (M48),
6. Study of socio-economical and financial cost of track installation work for residents and nearby shops (M48).

![Urban Track – SP 4]

**LCC calculations and evaluation**

- LCC calculations by SP1 (M24) and SP2 (M36) to **support research in laboratory situation**
  - Comparison of a two prognoses: A state-of-the-art-solution compared to an UrbanTrack-developed new solution for a hypothetic site (based on assumptions)

- LCC calculations by SP3: **Prognosis of expected results „Pre-Installation“** based on individual maintenance regime and cost structure of the operator (M36).
  - Comparison of two prognoses: A state-of-the-art-solution in comparison to an Urban Track-developed new solution for the specific building site (based on assumptions)

- LCC calculations by SP3: **Evaluation of expected results „Post-Installation“** based on individual maintenance regime and cost structure of the operator (M48).
  - Comparison of one prognosis to one analysis: "pre-installation" LCC-prognosis (M36) compared to an updated calculation of the same case considering lessons learned from reality (measurements, improvements, feedbacks) for the specific building site (based on real investment and costs)

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Figure 4.1: Example of a presentation slide shown and sent out to calculators-to-be
The tasks 3, 4 and 5 are the core of SP4. Once the LCC model and the LCC tool have been developed and tested, it is only logical to use them in order to evaluate new systems and methods developed within Urban Track. LCC calculations were then carried out by partners within SP1, SP2 and SP3 for different stages of their work packages:

1. **LCC calculations for the new developed systems and methods within SP1 and SP2 (M24/M36)**

   In the case of SP1, a comparison of two prognoses was made: state-of-the-art-solution compared to an Urban Track-developed new solution for a hypothetic site (based on assumptions). For SP2, a new maintenance technique was compared to the current one being used.

2. **LCC calculations for the on-test sites “Pre-Installation”**

   A prognosis of expected results of the new systems being installed or that will be installed was made. This prognosis is based on individual maintenance regime and cost structure of the operator. At this stage, a state-of-the-art-solution is compared to an Urban Track-developed new solution for the specific building site (it may still be based on assumptions).

3. **LCC calculations for the on-test site after installation**

   The goal here was to be able to assess the performance of the on-site tests for their complete lifetime and to measure the LCC outcome for the complete lifetime of the infrastructure. Due to time constraints of this European research project (only 48 months of duration), forecasts into the future must be done regarding the behaviour of the installed system.

   Here, once again, a comparison was made between the LCC prognosis before installation and the updated calculation of the same case considering lessons learned from reality (measurements, improvements, feedbacks) and the forecast predicted for the specific building site (to be based on real investment and costs).

These issues were explained to calculators to sensitise them for the LCC evaluation process.

The present deliverable deals with the results of the LCC calculations for the on-site tests which were carried out by the SP3 partners.
4.3. **LIFE CYCLE COSTING (LCC) MEETING EN 60300-3-3**

4.3.1. **Methodology of LCC**

The term « Life Cycle Cost » (LCC) recently had been quite often misinterpreted: LCC does not deal only with maintenance or waste disposal issues. Lifecycle Cost means: « Take all expenditures into account which might occur during the entire lifetime of a product (...of a project, a process). In this analysis, it is not important if the money is spent as an initial investment (taken into account depreciation of initial investment over the years) or for an ongoing and recurring activities. The relevant standard EN30300-3-3 refers to this entirety as LCC and states clearly, that besides the operational cost (mentioned as « ownership cost ») the investment (referred to as « acquisition cost ») plays an important role.

![Urban Track – SP 4](Image)

**Introduction to LCC**

**TCO – Total Cost of Ownership**

Both cost elements are linked together via the quality of the product (of the project, of the process): The higher the quality is valued, the more expensive the initial investment will be, but the investor will be (or at least, should be) able to save funds in the course of the lifecycle for less maintenance, less energy consumption etc. pp.).
Basically the individual strategy to be set up should aim at:

- Either «a maximum quality within a given LCC-budget» - a lesson to be learned is «don’t buy the cheapest solution all the time».
- Or, «the quality / requirements (e.g. performance or safety) are fixed».

There are two possibilities to lower the overall cost. The short-term oriented solution is «buy cheaper, but don’t increase the maintenance », the more long-term oriented approach might be «spend a little more money in the beginning, but save a lot afterwards». As railway business in general is looking for bigger time schedules than a lot of other industries, the appropriate approach is obvious.

**Figure 4.3: Timing of LCC analysis**

Time schedules leads to two other important aspects: responsibility and impact.

As Figure 4.3 shows clearly there is a big difference in cost generation («when and where do costs incur? ») and cost determination («who is responsible, who defines, when and where which costs occur? »). Of course the biggest impacts are seen while predefining a general technical solution (e.g. driving a car is obviously more expensive compared to cycling or walking) – responsibility of the buyer. Following that the buyer (or in terms of railways: the integrated enterprise, hence the infrastructure operator) should analyze carefully the overall LCC-aspects while doing first feasibility studies or deciding about the entire system. The earlier this takes place, the bigger is the amount of «reachable cost elements» – once a person has taken the decision to drive the car, the necessity of
spending money into tires, fuel, insurance and the car itself is a very logic follow-up. Since the car is designed, manufactured, provided and (at least in most cases) maintained neither by the one driving the car nor the one taking the decision to have a car at all (and which car…), the necessary solution is: «The Provider of the product must care not only about investment, but also about the subsequent expenditures of the user». The buyer has to point out, that this deems to him as an important area at all.

For a light rail vehicle the assumption from good practice is also stated in Figure 4.3: 80% of the overall LCC in an average lifespan from about 15 – 20 years are determined in the design phase. For an infrastructure object this ratio might be even lower investment versus even higher long-term cost – the lifetime of an infrastructure is much longer.

The above mentioned correlation is perfectly clear in the automobile industry – and might be considered as THE reason, why a lot of technical innovations are driven by automobile developments – long before the railway industry even thinks about that (good example: use of LEDs in rear and headlights led to significant savings in maintenance and energy consumption).

The EN standard recommends that the initial step in performing a LCC-calculation is to setup a model. (Remember: A model is a simplified picture of a complex reality). The model should be as complex as necessary (to take into account the most important contributing elements) but as simple as possible (to avoid getting stuck with lots of missing data). The Cost Element Concept of EN 60300-3-3 pictures a three dimensional matrix structuring the entirety of the total LCC: Life cycle phase, technical structure and the
different cost classes. Modelling should be done right at the beginning of every project in order to
generate a model which responds to the specific needs of the individual question: there is no general
applicable LCC-Model for all LCC-calculations.

4.3.2. LCC model for (Urban) railway infrastructure

The LCC-model for Urban Track takes into account the most important activities in rail infrastructure
(e.g. investment, maintenance, energy consumption, hindrance, renewal, and disposal) in the cost classes
(personal cost, material cost, energy cost, interest). The technical structure may be individually build up
starting on a very high level (e.g. network, routes) top down into greater detail (e.g. rail, rail fastener,
switch tongue). LCC in Urban Track means only internal cost (which are to be paid by the individual
enterprise), while the external cost (which are to be paid - if any - by the society: e.g. CO2, noise,
pollution) are named as Socio-Economic Cost. Both areas pictured in the Urban Track LCC-model and
can be calculated individually (and separately) and combined afterwards.

![Figure 4.5: LCC-Model Urban Track, cost elements on LCC- and SEC-side](image)
4.3.3. LCC-calculation tool InfraCaLCC®

The Urban Track LCC/SEC-model (at least the two dimensions Lifecycle Phase and Cost Classes) is readily implemented in the calculation tool www.infracalcc.de, while the third dimension can be structured by the individual user according to his / her individual needs.

Screenshots of Release 2.0 Beta – General Enhancements

To obtain a general introduction / overview as well as detailed information about the tool’s

- User’s interface
- Structure
- Functions
- Workflow
- Calculation
- Reporting

Please refer to the Report Deliverable D4.2 “LCC Calculation – Development of a software tool” (M24). This chapter is meant to be understood only as an updating add-on to that deliverable highlighting the most important differences (vs. release 1.1, M24).

Amongst the more visible improvements is the adapted user interface: new menu styles and the introduction of icons ease the first steps inside the tool.

Figure 4.6: “Welcome-Screen”, English

Also a very important improvement is the release of a new report (“detailed report”, see figure 4.7 at the next page): This document provides the full set of given detail information for each cost element – a very
useful report for executing quality checks as well as for each calculator to obtain (and print for documentation issue) a comprehensive overview about the entire input information of a “case”.

<table>
<thead>
<tr>
<th>Cost Element</th>
<th>Safety Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Switch tongue</td>
</tr>
<tr>
<td>Component</td>
<td>Operation</td>
</tr>
<tr>
<td>Phase</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>ID</td>
</tr>
<tr>
<td></td>
<td>1431</td>
</tr>
<tr>
<td>Interest Rate</td>
<td>0 %</td>
</tr>
<tr>
<td>Residual Value</td>
<td>false</td>
</tr>
<tr>
<td>Calculation</td>
<td></td>
</tr>
<tr>
<td>Starts in year</td>
<td>1</td>
</tr>
<tr>
<td>Number per Year</td>
<td>2.0</td>
</tr>
<tr>
<td>Number per Week</td>
<td>0.0</td>
</tr>
<tr>
<td>Third Party Cost</td>
<td>0 €/m</td>
</tr>
<tr>
<td>Incidental Expenses</td>
<td>0 €/m</td>
</tr>
<tr>
<td>Cost Cycle</td>
<td>0</td>
</tr>
<tr>
<td>Effort Skilled Worker</td>
<td>0 h/m</td>
</tr>
<tr>
<td></td>
<td>Effort Technician</td>
</tr>
</tbody>
</table>

Figure 4.7: Extract from Detailed Report, single cost element

Figure 4.8: Analysis Area
4.3.3.1. Languages (WP3.15)

Specification & Requirements

As the tool is used in an international context it has been implemented entirely (surface and contents) in English language – the only exception has been the user interface / surface, which had been already available in German. To achieve a real multilingualism and enable the usage of the most important EC-languages, the structure of the software had to be changed slightly and the translation had to be done. The objective of the work package has been therefore, to implement in addition to English the following languages:

- German
- French
- Spanish

Realization

Before starting the individual session the user has to set up preferences (the language to display) within the browser. Using Firefox-Mozilla® it has to be done while choosing the preferred language – if an individual page supports this language it will be shown using that language.
InfraCaLCC® supports now besides English the languages German, Spanish and French – if the individual browser is set up appropriate not only the surface will be displayed in the chosen language but also the contents (e.g. the pull down menus).
Bienvenue à LCC d’Urban Track

Sous projet 4 - Coût de Cycle de Vie d’Urban Track (LCC)

Ce SP se traduit par une méthode contrôlée pour évaluer les avantages des coûts du cycle de vie des solutions technologiques innovantes et faciliter le développement conjoint entre les opérateurs de réseaux ou les gestionnaires d’infrastructures et le secteur de la construction. Les résultats (évaluations) permettent aux opérateurs des réseaux ou gestionnaires de l’infrastructure et les décideurs politiques d’évaluer l’impact de la technologie de pointe de l’Horizon en termes de disponibilité de la voie, sécurité et les avantages environnementaux et de maintenance.

Christian Troscher (Rie Ingenieurwerkstatt GmbH)
Gerald Hamoullier (TRK)

Figure 4.11: “Welcome-Screen”, French

Bienvenido a LCC de Urban Track

Subproyecto 4 - Costos de Ciclo de Vida de Urban Track (LCC)

Este SP se traduce en una metodología para evaluar los beneficios de los costos del ciclo de vida de soluciones tecnológicas innovadoras y facilitar el desarrollo conjunto entre operadores de red o gestores de infraestructuras y la industria. Los “resultados” (evaluaciones) permiten a los operadores de red o administradores de la infraestructura y a los responsables de decisiones políticas evaluar la efectividad de la tecnología líder en hardware de última generación en términos de la disponibilidad de la vía, seguridad y los beneficios ambientales y de mantenimiento. Para más información acerca de los servicios adicionales ofrecidos para el uso de la herramienta de LCC (por ej. formación, apoyo al usuario, acceso a la base de conocimiento), diríjase a contactanos:

Christian Troscher (Rie Ingenieurwerkstatt GmbH)
Gerald Hamoullier (TRK)

Figure 4.12: “Welcome-Screen”, Spanish
The translation is realized via transfer spreadsheets as an integral part of the software – so it is possible to further modify or correct single words without the necessity to change the code itself. Only super users have the possibility to modify / change the contents of these tables (see figure 4.14).

So not only the “topmost surface” of the user interface appears in the chosen language, but also the detailed masks as well as even the contents of the pull down menus.
4.3.3.2. **Inclusion of socio-economic assessment methodology (WP3.15)**

**Specification & Requirements**

The aim of a socio-economic cost benefit analysis (SEC) is to map all relevant impacts and risks of the works in order to take an informed decision of the method to use for the installation/renewal of the rail infrastructure. The impacts are organized according to level of impact: building site, quarter/city and global (see Figure 4.16: Overview of Quantitative (black) and Qualitative (red) impacts) and phase: during construction, during operation or during maintenance/refurbishment. For each category of impacts and phases the most important indicators are defined. With the choice of indicators we have tried to look for effects of the different techniques that can be ‘manipulated’ or ‘affected’ by the developers of those techniques. Indicators like ‘noise’ and ‘vibrations’ but also ‘eco-indicator’ are directly linked to the technology. This means that changes in the design have a direct measurable effect on those indicators. For more information about the socio-economic methodology we refer to deliverable 4.7 ‘Socio-economic costs of track installation for residents at validation sites (SP3)”.

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**Figure 4.15: Definition of a track section, Spanish**
Figure 4.16: Overview of Quantitative (black) and Qualitative (red) impacts

The results from the already performed LCC-Cases show that the socio economic impact is a very relevant factor for Lifecycle-Costing – sometimes even the crucial cost element. Till now the calculators have been using a “rough and dirty” implemented possibility within the tool to take the socio economic impact into account. The socio-economic costs were just a plain number without further detail and could
be entered at the level of a cost element (see Figure 4.17: Cost element with input field for socio-economic costs).

Figure 4.17: Cost element with input field for socio-economic costs
With the integration of the socio-economic costs into the web-based LCC tool it should be possible to calculate both the socio-economic costs as the LCC values for a certain case and to compare them with each other.

One of the challenges was how to combine both calculation methods into one tool as there are differences in definitions and wording. Basically the socio-economic calculations are based on the impacts and cost on level of the location meanwhile the LCC calculations are based on the costs of the track sections. This means that the smallest unit for the calculations is different which has an impact on the way how the results can be interpreted. Different track sections can be part of one socio-economic location.

Figure 4.18: Conceptual representation of integration of SEC and LCC calculations shows a conceptual representation of the two LCC and the SEC calculations within the same tool. The common element is the network. Here it is possible to enter general information needed for the LCC calculations (energy price and hourly rates) and to give a name to the network. From here it is possible to go directly to LCC calculations by choosing ‘add track section’ or ‘route’. For SEC calculations it is necessary to define a route first. On the next level we find the track sections for LCC calculations and SEC cases (locations) for the socio-economic calculations. For both types of calculations this is the place to enter location-specific information that will be used for the calculations of the cost elements (LCC) and the activities (SEC). For socio-economic calculations it is necessary to give information about the system which will be used for the calculation of costs during operation. Subsequently it is possible to enter system-specific information for installation and maintenance activities. For the LCC calculations information about the cost elements for operation, installation and maintenance has to be added.

As track sections are defined as coherent parts of track it is very likely that there are several track sections within one SEC-case (or socio-economic location). Figure 4.19: Different examples of relation between LCC and SEC costs gives an overview of an overview of impact on LCC and SEC costs for 4 different possibilities. In the first case the track section is situated in between two intersections which causes hindrance for

Figure 4.19: Different examples of relation between LCC and SEC costs
traffic in between those intersections and one stop for public transport is out of service. If we look at example 2, we see a track section with the same size, but with a different socio-economic impact. In this case more streets are affected by traffic hindrance and more public transport stops are out of service. Also the detour for car traffic and public transport is longer. So the same size of track section with the same LCC costs can have a significant higher SEC cost. Example 3 and 4 show only a small difference in SEC costs as only the difference in length of the track sections has an impact on the cost. In this case there will be more households and businesses affected in the 4th example leading to higher socio-economic costs.

Figure 4.19: Different examples of relation between LCC and SEC costs
To enable comparison of results of the LCC and the SEC calculations, the counting of years has to be consistent.

![Diagram](image.png)

Figure 4.20: Allocation of time for installation and lifecycle for LCC and SEC shows a conceptual idea of the way how time is taken into consideration. The implementation of the project starts at ‘0’, so the time for installation will be allocated to the first year after the start of the project. For costs made before the start of the project, so before ‘0’, interest will be taken into account. This is only the case for LCC cost as there are no investments for SEC foreseen.

4.3.3.3. **Realization including Reports**

In this section we will give an overview of the implementation of the SEC into the LCC tool. For detailed information about the SEC costs and the way how they are calculated, we refer to deliverable 4.7.

General information applying to the network can be consulted in the section ‘Master data’ on the Welcome Page (see Figure 4.21: Welcome page with option to see the country-specific values). The menu-item ‘Countries’ gives a list of countries for which country-specific values are entered that will be used in the SEC calculations (Figure 4.22: List of Countries).
The country-specific values can be consulted at two locations in the tool: by clicking the country of choice from the country list (Figure 4.22: List of Countries and Figure 4.23: Country Specific Values) or at the moment a country can be chosen as part of the General Parameters of the SEC-Case (Figure 4.24: Country Specific Values – sub screen of SEC-Case). Only the super user has the rights to change the country-specific values.
To be able to carry out SEC calculations, it is necessary to define a route. From here a choice can be made between Track Section and SEC-Case (Figure 4.25: SEC-Case input screen).

<table>
<thead>
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<th>Country Specific Values</th>
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</thead>
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<td><strong>Country Code</strong></td>
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</tr>
<tr>
<td><strong>Name</strong></td>
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<tr>
<td><strong>Marginal Climate Change Cost</strong></td>
<td>(€/1000km)</td>
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<tr>
<td><strong>Passenger Car</strong></td>
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<tr>
<td><strong>Heavy Duty Vehicle</strong></td>
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</tr>
<tr>
<td><strong>Ship</strong></td>
<td>2.91 [€/1000km]</td>
</tr>
<tr>
<td><strong>Train</strong></td>
<td>317.82 [€/1000km]</td>
</tr>
<tr>
<td><strong>Tunnel</strong></td>
<td>73.49 [€/km]</td>
</tr>
<tr>
<td><strong>Free Access</strong></td>
<td>0.7 [€/km]</td>
</tr>
<tr>
<td><strong>Launch</strong></td>
<td>73.49 [€/km]</td>
</tr>
</tbody>
</table>
Figure 4.25: SEC-Case input screen

The SEC-Case comprises information about the location that will be used for the calculation of underlying SEC-variations (different systems). Subsequently information about the SEC-Variation can be entered like the name of the system and the estimated noise and vibration reductions. The last step is the definition of the installation and maintenance activities for each system (Figure 4.26: SEC-Variation input screen).

Figure 4.26: SEC-Variation input screen
Figure 4.27: SEC-Activity input screen – installation

The SEC-Activity input screens for installation and maintenance are very similar. The most important difference is the information about the activity cycle and occurrence per year of the maintenance activities.

The input screens SEC-Case, SEC-Variation and SEC-Activity have the option to get an immediate overview of the results by using the button ‘Compute’. The presentation of the results depends on the level of the calculation, but is always based on all underlying data as well. Figure 4.28: Results SEC-Case till Figure 4.31: Results SEC-Activity show the different result sheets.

Figure 4.28: Results SEC-Case
### Figure 4.29: Results SEC-Variation

<table>
<thead>
<tr>
<th>ID</th>
<th>System</th>
<th>Description</th>
<th>Sum of SEC for Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>205</td>
<td>COM</td>
<td>Re-Modular</td>
<td>-18,206,786.00 €</td>
</tr>
</tbody>
</table>

| Benefit Noise Reduction | 11,077,070.00 [€] |
| Benefit Variation Reduction | 7,108,241.90 [€] |
| Savings of SEC for Operation | 10,165,221.90 [€] |

### Figure 4.30: Results SEC-Variation

<table>
<thead>
<tr>
<th>ID</th>
<th>System</th>
<th>Description</th>
<th>Sum of SEC for Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>205</td>
<td>COM</td>
<td>Re-Modular</td>
<td>-18,206,786.00 €</td>
</tr>
</tbody>
</table>

| Benefit Noise Reduction | 11,077,070.00 [€] |
| Benefit Variation Reduction | 7,108,241.90 [€] |
| Savings of SEC for Operation | 10,165,221.90 [€] |

#### Details

- **Marginal Congestion Cost**: 540.60 [€]
- **Marginal Fuel Costs**: 97.52 [€]
- **Marginal Costs Road Safety**: 86.52 [€]
- **Marginal Noise Costs**: 22,106.83 [€]
- **Marginal Air Pollution Costs**: 43.61 [€]
- **Marginal Climate Change Costs**: 49.50 [€]
- **Public Transportation**:
  - Compensation Fee: 300.60 [€]
  - Loss of Income: 209,336.00 [€]
- **Building Site**
  - Benefit due to less traffic: -20.24 [€]
  - Noise costs due to construction: 21,135.65 [€]
  - Turnover Compensation: 35,000.00 [€]
- **Transportation of Materials**
  - Marginal Congestion Cost: 50.00 [€]
  - Marginal Costs Road Safety: 4.40 [€]
  - Marginal Noise Costs: 17.61 [€]
  - Marginal Air Pollution Costs: 33.61 [€]
  - Marginal Climate Change Costs: 12.62 [€]
- **Sum of SEC for Construction**: 310,914.00 [€]
Figure 4.31: Results SEC-Activity

Another option to look at the results is to carry out an analysis. The menu gives an immediate entrance to the SEC analysis section (Figure 4.32: Choice between LCC and SEC analysis).

Figure 4.32: Choice between LCC and SEC analysis

The analysis is carried out the same way as for LCC calculations. See figures Figure 4.33: Main screen Analysis till Figure 4.36: SEC detail report.

Figure 4.33: Main screen Analysis
Figure 4.34: Overview of total costs and cumulated costs

Figure 4.35: SEC analysis report

Figure 4.36: SEC detail report
4.3.4. Validation

The tool has been validated by carrying out test-calculations. The results of this test are shown in this section. The main conclusion is that the outcomes between the LCC-SEC tool and the original EXCEL tool are the same. The next figures show an example of a calculation: for the EXCEL tool both test-system 1 and test-system 2 and for the LCC-SEC tool test-system 2.

**Test 5 mei 2010**

<table>
<thead>
<tr>
<th>Tracklength</th>
<th>400 lmdt</th>
<th>Choose Country:</th>
<th>Europe</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>General</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type of area</td>
<td>Urban collector</td>
<td>Length of tracks to be constructed/maintained</td>
<td>lmdt</td>
</tr>
<tr>
<td>Traffic volume on building site before works (2 directions, 6.00 - 20.00)</td>
<td>12,000</td>
<td>Proportion HDV</td>
<td>2,00%</td>
</tr>
<tr>
<td><strong>Public Transport</strong></td>
<td></td>
<td>Number of service hours PT (per day)</td>
<td>20,0</td>
</tr>
<tr>
<td>Rail &amp; bus: average number of new passengers per stop</td>
<td>5</td>
<td>Rail &amp; bus: frequency per hour during operations</td>
<td>21</td>
</tr>
<tr>
<td><strong>Building site</strong></td>
<td></td>
<td>Households in construction area</td>
<td>100</td>
</tr>
<tr>
<td>Businesses in construction area</td>
<td>small</td>
<td>large</td>
<td>50</td>
</tr>
</tbody>
</table>

![Figure 4.37: Information about the location](image)

Figure 4.37: Information about the location
<table>
<thead>
<tr>
<th>OPERATION</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Life cycle years</td>
<td>30</td>
<td>30</td>
</tr>
<tr>
<td>Noise reduction aim dB</td>
<td>-1</td>
<td>-0.5</td>
</tr>
<tr>
<td>Vibrations reduction aim (groundborne noise) dB</td>
<td>-1</td>
<td>-0.5</td>
</tr>
</tbody>
</table>

Figure 4.38: General information about the SEC-Variation (system)
### INSTALLATION

<table>
<thead>
<tr>
<th>Description</th>
<th>Test system 1</th>
<th>Test system 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total duration of this phase</td>
<td>number of days</td>
<td>5</td>
</tr>
<tr>
<td>Total time hindrance for traffic</td>
<td>number of days</td>
<td>5</td>
</tr>
<tr>
<td>Total time hindrance for public transportation</td>
<td>number of days</td>
<td>5</td>
</tr>
<tr>
<td>Duration trams are replaced/day</td>
<td>hours</td>
<td>20.0</td>
</tr>
</tbody>
</table>

#### Normal traffic & public transport during works

<table>
<thead>
<tr>
<th>Description</th>
<th>Test system 1</th>
<th>Test system 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of street with traffic hindrance</td>
<td>number of meters</td>
<td>600</td>
</tr>
<tr>
<td>Cars: extra length route during works</td>
<td>meters</td>
<td>1,000</td>
</tr>
<tr>
<td>Cars: volume of traffic on building site during works</td>
<td>% of normal</td>
<td>60%</td>
</tr>
<tr>
<td>Rail: extra length route during works</td>
<td>meters</td>
<td>1,200</td>
</tr>
<tr>
<td>Rail: number of vehicles/hour</td>
<td>number</td>
<td>21</td>
</tr>
<tr>
<td>Replacement busses: length route during works</td>
<td>meters</td>
<td>0</td>
</tr>
<tr>
<td>Replacement busses: number of vehicles/hour</td>
<td>number</td>
<td>0</td>
</tr>
<tr>
<td>Rail &amp; bus: number of stops temporary out of service</td>
<td>number</td>
<td>2</td>
</tr>
<tr>
<td>Rail &amp; bus: % PT passengers using alternative stop</td>
<td>%</td>
<td>25%</td>
</tr>
</tbody>
</table>

### Building site

<table>
<thead>
<tr>
<th>Description</th>
<th>Test system 1</th>
<th>Test system 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessibility for pedestrians</td>
<td>value in [0;1] (0=no; 1=completely)</td>
<td>0.8</td>
</tr>
<tr>
<td>Accessibility for cars or PT (within 200m)</td>
<td>value in [0;1] (0=no; 1=completely)</td>
<td>0.5</td>
</tr>
<tr>
<td>Extra Noise due to works (at 8 m distance from source)</td>
<td>mean in dB</td>
<td>10</td>
</tr>
</tbody>
</table>

### Transport materials

<table>
<thead>
<tr>
<th>Description</th>
<th>Test system 1</th>
<th>Test system 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Truck: Distance over which modules have to be transported</td>
<td>km per TRUCK</td>
<td>400</td>
</tr>
<tr>
<td>Truck: Number of trucks needed for the transport</td>
<td>number of TRUCKS</td>
<td>28</td>
</tr>
<tr>
<td>Ship: Distance over which modules have to be transported</td>
<td>km per SHIP</td>
<td>0</td>
</tr>
<tr>
<td>Ship: Number of ships needed for the transport</td>
<td>number of SHIPS</td>
<td>0</td>
</tr>
<tr>
<td>Ship: Tons per ship</td>
<td>tons per SHIP</td>
<td>0</td>
</tr>
<tr>
<td>Train: Distance over which modules have to be transported</td>
<td>km per TRAIN WAGON</td>
<td>0</td>
</tr>
<tr>
<td>Train: Number of train wagons needed for transport</td>
<td>number of TRAIN WAGONS</td>
<td>0</td>
</tr>
</tbody>
</table>

### Transportation of Materials

<table>
<thead>
<tr>
<th>Description</th>
<th>Test system 1</th>
<th>Test system 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distance for Trucks</td>
<td>50.0 [km]</td>
<td></td>
</tr>
<tr>
<td>Number of Trucks</td>
<td>84.0</td>
<td></td>
</tr>
<tr>
<td>Distance for Ships</td>
<td>0.0 [km]</td>
<td></td>
</tr>
<tr>
<td>Number of Ships</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Tons per Ship</td>
<td>0.0</td>
<td></td>
</tr>
<tr>
<td>Distance for Trains</td>
<td>0.0 [km]</td>
<td></td>
</tr>
<tr>
<td>Number of Wagons</td>
<td>0.0</td>
<td></td>
</tr>
</tbody>
</table>

---

Figure 4.39: Information about the Activity
<table>
<thead>
<tr>
<th>Installation Costs</th>
<th>Test system 1</th>
<th>Test system 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transportation of modules</td>
<td>11,519 €</td>
<td>4,320 €</td>
</tr>
<tr>
<td>DETOUR Installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Congestion + Fuel</td>
<td>14,163 €</td>
<td>74,356 €</td>
</tr>
<tr>
<td>Noise (Traffic)</td>
<td>517 €</td>
<td>2,712 €</td>
</tr>
<tr>
<td>Emissions</td>
<td>947 €</td>
<td>4,971 €</td>
</tr>
<tr>
<td>Climate Change</td>
<td>1,100 €</td>
<td>5,775 €</td>
</tr>
<tr>
<td>Road Safety</td>
<td>1,769 €</td>
<td>9,394 €</td>
</tr>
<tr>
<td>PT Installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Compensation Fee</td>
<td>50,400 €</td>
<td>201,600 €</td>
</tr>
<tr>
<td>Loss of Income</td>
<td>11,025 €</td>
<td>44,100 €</td>
</tr>
<tr>
<td>BUILDING SITE Installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Turnover Compensation</td>
<td>17,500 €</td>
<td>52,500 €</td>
</tr>
<tr>
<td>Noise (Traffic)</td>
<td>-310 €</td>
<td>-1,627 €</td>
</tr>
<tr>
<td>Noise (Construction)</td>
<td>1,115 €</td>
<td>2,231 €</td>
</tr>
<tr>
<td>TOTAL - Installation</td>
<td>109,765 €</td>
<td>400,331 €</td>
</tr>
<tr>
<td>Total Duration of Works (days)</td>
<td>5,0</td>
<td>20,0</td>
</tr>
<tr>
<td>Total Time Hindrance for Traffic (days)</td>
<td>5,0</td>
<td>15,0</td>
</tr>
<tr>
<td>Total Time Hindrance for PT (days)</td>
<td>5,0</td>
<td>20,0</td>
</tr>
</tbody>
</table>

**Figure 4.0: Results**
4.3.3.5. Knowledge base (WP.315)

Specification & Requirements
The prototype knowledgebase of the tool is subject to requests at the time being, as there is available the anonymized knowledge of exemplary cases. Unfortunately the usability as well as the reporting in this area had been quite poor – a field for very much needed improvements. The objective of the work package has been therefore the realization of major improvements in the data insertion process, of the tool’s usability in searching and tracing information and the implementation of some basic statistics.

Realization including reports
Data insertion process is now supported by filtering functions in each column (same function as in MS-EXCEL®) - this feature is now available for standard users (figure 4.41) as well as for super users (figure 4.42).

Figure 4.41: Searching, filtering and sorting (standard user)
Basic statistics (average, median, standard deviation and variance) are implemented: User may choose a set of elements from the knowledge base, and the values are calculated immediately.
The above mentioned new report “detailed report” assists also in using the knowledge base: User may identify one or more appropriate elements by the unique ID number, and the detailed report displays also the ID number – printable e.g. for documentation purposes.

<table>
<thead>
<tr>
<th>Cost Element</th>
<th>Safety Check</th>
</tr>
</thead>
<tbody>
<tr>
<td>Description</td>
<td>Switch tongue</td>
</tr>
<tr>
<td>Component</td>
<td>Operation</td>
</tr>
<tr>
<td>Phase</td>
<td></td>
</tr>
<tr>
<td>Activity</td>
<td>check</td>
</tr>
<tr>
<td>ID</td>
<td>1431</td>
</tr>
<tr>
<td>Type</td>
<td></td>
</tr>
<tr>
<td>Interest Rate</td>
<td>0 %</td>
</tr>
<tr>
<td>Inflation Rate</td>
<td>0 %</td>
</tr>
<tr>
<td>Residual Value</td>
<td>false</td>
</tr>
<tr>
<td>Socio economic Cost</td>
<td>0 €</td>
</tr>
<tr>
<td>Calculation</td>
<td></td>
</tr>
<tr>
<td>Starts in year</td>
<td>1</td>
</tr>
<tr>
<td>End year</td>
<td>30</td>
</tr>
<tr>
<td>Number per Year</td>
<td>2.0</td>
</tr>
<tr>
<td>Number per Month</td>
<td>0.0</td>
</tr>
<tr>
<td>Number per Week</td>
<td>0.0</td>
</tr>
<tr>
<td>Number per Day</td>
<td>0.0</td>
</tr>
<tr>
<td>Material Cost</td>
<td>0 €/m</td>
</tr>
<tr>
<td>Third Party Cost</td>
<td>0 €/m</td>
</tr>
<tr>
<td>Energy Consumption</td>
<td>0 kwh/m</td>
</tr>
<tr>
<td>Incidental Expenses</td>
<td>0 €/m</td>
</tr>
<tr>
<td>Resources</td>
<td>0 €/m</td>
</tr>
<tr>
<td>Cost Cycle</td>
<td>0</td>
</tr>
<tr>
<td>Failure Rate</td>
<td>null h</td>
</tr>
<tr>
<td>Effort Engineer</td>
<td>0 h/m</td>
</tr>
<tr>
<td>Effort Skilled Worker</td>
<td>0 h/m</td>
</tr>
<tr>
<td>Effort Technician</td>
<td>0.05 h/m</td>
</tr>
</tbody>
</table>
4.3.4. **Wider European consensus on the project internal commonly agreed harmonised LCC calculation, as well as socio-economic assessment methodologies for urban rail infrastructure (WP3.16)**

To reach a wider European consensus on LCC-analysis, various infrastructure operators were contacted directly and indirectly via industry multipliers. This ensured the involvement of the industry in the consensus building process in addition to the focussed infrastructure operators.

In the next step the interested operators were visited or via phone conference informed in detailed about both calculation methodologies, the offer of LCC calculations free of charge and the required data to provide. In addition, the operators were invited to participate in the Urban Track LCC calculation workshop that took place in February 2010.

To open an easy access to the required data a checklist asking for a not pre-defined data set was prepared in English, French and German and provided to the operators and asked to fill them out. On these data an LCC-calculation could be carried without to much effort.

In total 31 infrastructure operators all over Europe were contacted:

- 1 from Austria,
- 1 from Belgium,
- 1 from Finland,
- 2 from France,
- 11 from Germany (boosted by mouth-to-mouth propaganda),
- 1 from Ireland,
- 2 from The Netherlands,
- 2 from Norway,
- 1 from Portugal,
- 1 from Poland,
- 1 from Spain,
- 4 from Switzerland,
- 1 from Sweden
- 2 from United Kingdom.

Most of the operators were interested in a harmonised economic assessment methodology. Only three of the 31 were not interested in a further appliance of the methodologies in their companies.

Of the 31 contracted operators stated 21 a deep interest, but had to decline a participation in this project. There were two main reasons for this,

- time frame too narrow or
- non-availability of personnel.
Both of them finally lead to one: the data collection process is a time consuming task, which is similar to the experiences with the partners within the Urban Track project.

There is a big interest in both economic assessment methodologies all over Europe. In addition, a harmonisation is most welcome. Nearly all visited operators see the benefits of applying such methodologies and want to go forward on this track in the future.

Data availability is in most companies difficult. Either no detailed cost account exists or the collection process needs a lot of time.

A methodology to assess socio-economic costs for product decision seems to be a missing link for discussions between infrastructure operators and city authorities as well as politicians.
4.4. **SEVILLE CASE (EXAMPLE) “RAIL/ROAD INTERFACE AND FINISHING LAYER”**

The objective of this WP was the installation of a prefabricated track that consolidated the results obtained in WP 1.2.2. The WP leader was FA-DGT and as well responsible for the calculations. The creation of the maintenance plan and the related calculations themselves were carried by TTK with contribution of FA-DGT, CDM and INECO.

4.4.1. **Structure of the Product**

The Material chosen for the interface had to:
- be elastic in a large deflection range, without creep and permanent deformation.
- bind very well with steel and concrete.
- resist in a large temperature range.
- be maintenance free.
- be protective against stray current.

**FFAA Functional requirements:**
- 2. Type of rail: Ri60N
- Inclination of the rail: 1/1
- Width of track:
  - Double track
  - Platform width: 8m
  - G.L.O.: 7.30m
  - Distance between track axes: 3.80m
  - Track gauge: 1435+2-1 mm
- Axle load: 120 kN
- Minimum curve on track
  - Roundabout Malasmananas (initially Cabeza Hermosa): no curving
  - Crossing Avenida Constitución: curve radius 175m
- Electrical resistance: yet to be defined
- Tolerances table (Installation and in service):
  - Transversal alignment < 2mm
  - Longitudinal alignment < 2mm
- Track gauge: 1435+2-1 mm

Different options of finishing layer material for MODULIX were analysed:
- Bound pavement: 8-12 cm
- Asphalt
- Natural stone

Several tests were carried out at COLAs laboratories to analyse which finishing layer shows to the best performances of endurance and the best results were shown by the concrete and bound pavement.
4.4.2. Description of test site

Two different types of prefabricated modules were installed and tested in Alcalá de Guadaíra (Seville) in order to validate the choices of finishing layers and the rail/street pavement interface.

For this example the Alcala de Guadaíra Site in Ferrocarriles Andaluces (FFAA) Network was:

- Crossing Constitución Avenue: installation of 36 lmldt in iX-Modulix (integrated FST) – this crossing is highly transited.

![Location of the two test sites in Alcalá de Guadaíra](image1)

The section with iX Modulix (CDM-QT-iX-Slab) had a cover of block paving.

![Installation site n°2 in Av. Constitución](image2)

---

1 Source: Transportation Research Institute, Hasselt University
Reference case: Rheda city

Because iX-Modulix were built as part of a new light rail line (14 km long), there was not a previous system to compare it to. In order to carry out LCC analysis, it was decided then to compare it to an alternative system that could have been chosen instead. Ferrocarriles de Andalucía had already analysed two other alternative systems:
- Corkelaste
- Rheda city (which was used for the rest of the light rail line).

For the LCC calculations, it was decided that the reference case will be Rheda City.

---

2 (1) Source: Rail.one; Rheda City Brochure
**Case study: Rheda City vs. IX-Modulix**

In this case, the track specifications of Constitución Avenue Crossing were selected. In addition, it was defined:

- as reference case: 72 lmst of Rheda City with a track cover of paving-stones and
- as comparison case: 72 lmst of IX-Modulix with a track cover of paving-stones with concrete cover.

In this particular crossing Ferrocarriles de Andalucía selected paving-stones as track cover for the IX-Modulix. Therefore, the reference case must also have the same track cover.
### LCC Parameters and results

The following boundary conditions have been applied for the LCC calculation of both study cases:

- **Wage rates:**
  - Engineer: 48 Euro/h
  - Technician: 30 Euro/h
  - Skilled labour: 19 Euro/h
- **Energy cost:** N/A

As mentioned earlier, the lengths of the sections was the following:

- Crossing Constitución Avenue: installation of 38 lmtd in iX-Modulix

**Defined Life Cycles of the tested systems:**

- Rheda City: 30 years
- iX-Modulix: 30 years

**Period under consideration:** 50 years

**Financial aspects:**

- Interest rate: 5 %
- Inflation rate: 2 %

The considered activities and LCC related cycles of the studied systems are the following:

<table>
<thead>
<tr>
<th>Activities/Cost elements</th>
<th>Frequencies “Reference case”</th>
<th>Frequencies of new system “iX-Modulix”</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Construction and Investment phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Construction and investment of track</td>
<td>Year 0 (lifetime 30 years)</td>
<td>Year 0 (lifetime 30 years)</td>
</tr>
<tr>
<td><strong>Operation and Maintenance phase</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inspection for Safety</td>
<td>Once every six weeks</td>
<td>Once every six weeks</td>
</tr>
<tr>
<td>Drainage cleaning</td>
<td>Every three months</td>
<td>Every three months</td>
</tr>
<tr>
<td>Rail cleaning</td>
<td>Every two months</td>
<td>Every two weeks</td>
</tr>
<tr>
<td>Rail grinding</td>
<td>Every two weeks</td>
<td>Every two weeks</td>
</tr>
<tr>
<td>Renewal of joints</td>
<td>Ever three years</td>
<td>---</td>
</tr>
<tr>
<td>Paving-stones cover retouch and milling</td>
<td>Every three years</td>
<td>---</td>
</tr>
<tr>
<td>Paving-stones renewal</td>
<td>Every seven years</td>
<td>---</td>
</tr>
<tr>
<td>Welding of joints</td>
<td>Once after fifteen years and twice between years 20 and 30</td>
<td>Once after fifteen years and twice between years 20 and 30</td>
</tr>
<tr>
<td>Welding of rail breaks</td>
<td>Once after fifteen years and twice between years 20 and 30</td>
<td>Once after fifteen years and twice between years 20 and 30</td>
</tr>
</tbody>
</table>

**Removal and Disposal phase**

| Removal of track infrastructure | Not considered | Not considered |

*Table 4.1: Considered maintenance activities of Rheda City and iX-Modulix*
Total results of LCC net present values for each system of scenario A (broken down by activity):

accumulated LCC over period under consideration of candidates

Table 4.2 (a): Overview of NPV for iX-Modulix and Rheda city (reference)
Table 4.3 (b): Overview of NPV for iX-Modulix and Rheda city (reference)

When comparing iX Modulix with Rheda City (both with a paving-stones surface), the results of LCC reduction were much different: 37% of LCC reduction. The main reason of this strong difference resided in the type of track cover: paving-stones. Even though the installation costs of iX Modulix were much higher than Rheda City’s (+70% difference), the maintenance costs of Rheda City with this particular cover were extremely high (nearly eight times higher than the maintenance costs of iX Modulix with the same cover).

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3 Reduction of NPV in % relative to Reference Case value.

4 In the case of IX-Modulix, a chemical adherent is used to glue together the stones. This chemical is poured between the stones and allows an excellent adherence of all paving-stones. The stones behave as one entity.
These results corroborate results from other SP of Urban Track, in particular those of D2.11 “New low cost renewal and refurbishment methods, tests at a Circular Testing Machine, embedded tracks and green tracks”.

In this work package, track systems with different surface types were tested. Three surface types studied were: asphalt (in two variants), pavement (in three variants) and concrete (in three variants). The test bodies were driven over in three temperature cycles at temperatures of -10°C; +10°C and +30°C room temperature respectively. Each cycle comprised approximately 330,000 wheel crossings (a total of almost 1 million crossings), thereby simulating an actual load of over 10 year. The only track covers that did not withstand the load were the pavement structure comprising natural stones secured with an elastic joint sealing compound.

The lesson to withdraw from this experience is that track systems with an application of paving-stones cover do NOT behave well in particularly highly transited corridors or crossings and should not be implemented in such areas. Maintenance costs in such cases are significant.
4.5. CONCLUSIONS

4.5.1. Conclusions regarding the LCC results obtained within SP3

The main ambition of Urban track was to develop and build an integrated family of “maintenance-free” modular track infrastructure solutions, that lead to a substantial reduction (fixed target of 25% of LCC reduction) in track global infrastructure costs, with a significant increase of the availability of track infrastructure.

Within the scopes of the work packages of SP 4, a LCC methodology and software tool were developed to enable other project partners to evaluate their new systems and procedures and to determine whether or not the expected LCC reduction is attained.

Pre-installation LCC prognosis

The figure below presents the expected LCC reduction (before installation) for all the systems and procedures developed within SP3.

For the most studied cases, the target of 25% of LCC reduction was met. In ten particular cases, it was more than doubled (WP 3.2 Sedum tracks and WP 3.12 Prefarail). The main factors influencing these reductions were, according to the calculator, the maintenance and adjustment costs of the green surface (WP 3.2) and the installation costs (with a ration of 4 to 1 within WP 3.12).

In four other cases, this target was not reached. These were:

- WP 3.5 Fast installation techniques in Bremen (20% of LCC reduction)
- WP 3.6 Alternative for floating slab track, still foundation plates in Brussels (19% of LCC reduction)
- WP 3.7 Implementation of Elastiplus in Brussels (23% of LCC reduction)
- WP 3.9 Re-Modulix in Karlsruhe (19% of LCC reduction)

However, in these four cases a significant LCC reduction close to the target was attained. Overall it must be stated that the tested systems present very promising results of LCC prognosis before installation into the test sites.
Post-installation analysis

As stated above, globally all pre-installation LCC analysis were very promising: all tested systems presented significant LCC reductions. However, in order to fully evaluate these systems, it was necessary to have real results of their performance over a certain number of years. Because Urban Track is only a four-year research project this date was not available.

Post-installation LCC calculations were carried out mainly through the first measurements on the site and on further prognosis based on these measurements. These analyses were carried out in the following installation sites:

- WP 3.6 Alternative for floating slab track, still foundation plates in Brussels: the implementation of the system was much cheaper than expected. The expected reduction in LCC was therefore beaten (30% of LCC reduction instead of 19%).
- WP 3.9 Re-Modulix in Karlsruhe: the expected LCC reduction was reduced by 9% due to track cover renewal after one year of operation, some cobble-stones tiles started to come off (10% of LCC reduction instead of 19%)
WP 3.10 Booted bi-block sleepers in Manila: The development of material prices was on the way down during the process construction tendering as well as during construction itself due to the financial crisis. Additionally the installation period was shorter than expected. Therefore less man hours were required than previously assumed. (32 respectively 37 % of LCC reduction instead of 30 respectively 35 %)

These post-installation analyses are very important: the first two cases introduced above show how LCC results after installation differ considerably from the first estimations carried out before installation.

Two additional cases were evaluated for the following installation sites:
- WP3.1 REMS in Madrid and
- WP 3.5 Fast installation techniques in Bremen.

The experiences with the both new system met any LCC relevant expectations and therefore no LCC calculations were required.

For the missing cases the inauguration of the test site was projected between May and August 2010. Because of this no LCC-related experiences with the implemented products were expected within the duration of the Urban Track project.

4.5.2. Lessons learned from the use of the LCC tool and methodology

Two lessons can be drawn from the development and the use of the LCC tool and methodology:

- **Awareness of application of broad approaches when selecting new track systems or evaluating procedures**: within the research community, the study of LCC and RAMS analysis and their applications on urban railway infrastructure is not something new. Many thesis works, publications and studies have been made on this subject for many years. For the community of European urban track infrastructure managers, LCC approaches are not as common. Thanks to the European project of Urban Track and the sub project SP4, an awareness of LCC approaches and methodologies has been either created or strengthened within many of the Urban Track partners and the user groups Networks of Operators and Industries. The SP4 team is very confident that this sub project has had a very positive impact on these partners and that the multiple advantages of the application of LCC approaches, especially for decision-making, have been disseminated.

- **Importance of specific cost element information depending on the level of analysis carried out**: this was the number one issue and number one limitation for all calculations throughout the four years of research. The more detailed and throughout information regarding the costs of installation, maintenance, operation and removal the better the LCC results could expected to be. Throughout numerous discussions with calculators, it has been found out that very few calculators disposed of detailed maintenance costs; the most informed being for some cases some operators. For the most part, assumptions regarding these costs had to be made or general costs for overall activities were used as input in the LCC software. This LCC tool is an expert-oriented tool. For the proper use of this tool and carrying out both “qualitative and quantitative” LCC analysis, it is very important to have...
the right cost element information at the right information level. In the practical cases studied within SP4, we see that this was a big obstacle because sometimes key data regarding cost elements was either missing or the LCC analysis was carried out on a too global level (without really detailing for instance all the necessary maintenance and operations activities).

4.5.3. Recommendations regarding further LCC applications

After 4 years dedicated at testing, developing, using and teaching other SP partners how to use this tool, the SP4 team identifies the following applications for LCC:

- **Going back to the source**: As mentioned earlier, the level and the detail of the information introduced in the tool is a critical issue. Through the different LCC analysis presented by SP1/SP2/SP3 partners, it was identified that some cost elements at certain levels are simply not available. In order to make the most use of this tool, it is very important of having key cost element information at certain levels. A possible application could be the development of better information channels within operators’ structures in order to gather, store and control this information on a regular basis. It was also identified within other work packages that cost transparency is an important issue regardless the type of infrastructure management structure (in-house-operations, all activities semi or completely segregated --> more about this subject is found in the deliverable D2.9).

- **Comparison of systems and procedures on a European level**: this tool serves several purposes of LCC evaluation. Among these, in particular two were find in:
  - Analysis of systems and their elements (types of track systems and their components)
  - Analysis of procedures (mainly construction procedures and maintenance regimes).

A further application area could be the use of the tool for carrying out specific systems and procedures comparison at a European level: for instance, the application of LCC analysis for the definition of maintenance regimes or the comparison of different types of maintenance regimes for specific track systems in Europe.

As stated earlier, today’s urban railway sector is imposing every day higher demands for service quality on railway infrastructure managers. Since railway infrastructure has a very long asset life, efficient maintenance planning is essential in order to meet these demands.

In addition, we identify that there are great differences in the different maintenance regimes observed within Urban Track partners. Even though many of these differences are related to the specific characteristics of the network in question, there are some other preventive activities that are carried out at very different intervals, indicating somewhat the maintenance philosophy of the network in question. Analysing these differences through a LCC optic on a European level could be a further application possibility.

- **Further dissemination of LCC Methodology within the European community of urban track managers and creation of a LCC discussion platform**: a small but rather effective application field could be the further dissemination of this methodology within the community of European operators and managers of track infrastructure. As stated earlier, on a research level many steps have been
taken for the study and development of LCC approaches. On a more practical level, the situation is somewhat different. This potential work could be oriented at establishing a bridge between current LCC developments and the operators’ community by creating a platform serving several purposes:

- Further dissemination of LCC Methodology developed within Urban track
- Exchange of current information of problems and solutions within each network
- Discussion regarding current practices regarding track construction and maintenance, their advantages and disadvantages...

This platform could be backed up by a web page posting new information, new meetings and most interesting discussions between participating partners.

4.5.4. **Recommendations regarding further Research**

The Methodology and software tool developed within SP4 allow carrying out assessments of the life cycle cost benefits of innovative technological solutions and procedures or to optimise maintenance regime on the existing infrastructure by analysing cost drivers. This methodology was not developed taking into account causalities\(^5\). For instance, the influence of certain parameters such as: radius class, load/speed class, installation type…was not taken into account for estimating the overall life cycle of the system and its components.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
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<tbody>
<tr>
<td>complete system</td>
<td>default system</td>
</tr>
<tr>
<td>maintenance method</td>
<td>MaintenanceMethod1</td>
</tr>
<tr>
<td>radius class</td>
<td>&gt;1830m</td>
</tr>
<tr>
<td>switch type</td>
<td>No switch or crossing</td>
</tr>
<tr>
<td>load class</td>
<td>10-11 million tons per year</td>
</tr>
<tr>
<td>gradient class</td>
<td>0%</td>
</tr>
<tr>
<td>cant class</td>
<td>&lt;33km</td>
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<tr>
<td>superstructure type</td>
<td>slab track</td>
</tr>
<tr>
<td>sleeper type</td>
<td>concrete Independent Block</td>
</tr>
<tr>
<td>installation type</td>
<td>Grade 4</td>
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<tr>
<td>track type</td>
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<td>climate class</td>
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<tr>
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<td>Quality Class 1000 minimum 980 N per mm tensile strength</td>
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</tr>
<tr>
<td>track width</td>
<td>medium</td>
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<tr>
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</tr>
</tbody>
</table>

Figure 4.51: Parameters having an influence on the overall life cycle expectancy

Through numerous discussions with Urban Track members and beyond, it was identified that it is very important to take into account the incidence of different parameters within the LCC tool. We identify that this could be a potential area of improvement.

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\(^5\) Causality relationship between an event (the cause) and a second event (the effect), where the second event is a consequence of the first (source: Wikipedia)
Determining the exact incidence of certain parameters on the overall life cycle is very complex. Among the many activities needed to determine the incidence of different factors, several types of tests will be needed on both laboratory and in-situ conditions.

Within SP2 (WP 222) a virtual maintenance tool was developed allowing the modelling and integration of track degradations in relation to inspection and maintenance rules. The degradation process of a system was studied, modelled and with this information, estimations were made regarding reliability and related metrics. The mathematical tool developed was able to unwind the life cycle of a specific component and carry out its interaction with the maintenance operations in accordance with a given strategy.

The idea for a future research is to develop within this LCC methodology further mathematical connections of the incidence of certain parameters for the overall estimation of the life cycle cost, especially maintenance related parameters.
4.6. RELATED DELIVERABLES / BACKGROUND INFORMATION AVAILABLE

Deliverables related to the software tool:
- D 4.1 - LCC Software Specification,
- D 4.2 – Software Tool for LCC calculation,
- D 3.15 - Report on advanced Software-Development and Validation,

Deliverables related to economic evaluation (LCC) of innovations, products and methods:
- D 4.3a - LCC calculations of all systems developed under SP1,
- D 4.3b - LCC calculations of all systems developed under SP2,
- D 4.4 - LCC calculations of all systems before installation (SP3),
- D 4.5 - Report on "LCC calculation of all systems after installation (SP3)"

Deliverables related to socio-economic evaluation of innovations, products and methods:
- D 4.6 - Methodology for Socio Economic costs of track installation for residents.
- D4.7 – Application report on “Socio-economic costs of track installation for residents at validation sites (SP3)"

Deliverable related to dissemination beyond the Urban Track project:
- D 3.16 - Report on “Additional LCC /socio-economic calculations for a wider European community”

In addition a joint Innotrack / Urban Track position paper on LCC had been prepared.

Beyond these deliverables a multilingual workspace at www.infracalcc.de has been developed and serves as entrance point for all users from outside Urban Track. Besides the link to the tool itself this workspace mainly deals with the necessary administrative issues (e.g. brand name, registration of new users, terms of use, dates and registration to training courses etc.). The workspace is also subject to individual disseminating activities, and up to date there have been approx. 4,500 visitors. Arising from that at the time being 71 users from 36 different organizations registered. Also the tool is already in use within different commercial infrastructure projects, light rail as well as heavy rail applications.
4.7. RELATION WITH THE OTHER DELIVERABLES (INPUT/OUTPUT/TIMING)

This chapter is related to the following deliverables:

- D4.1 - LCC Software Specification,
- D4.2 – Software Tool for LCC calculation,
- D3.15 – Report on advanced Software-Development and Validation,
- D4.3a - LCC calculations of all systems developed under SP1,
- D4.3b - LCC calculations of all systems developed under SP2,
- D4.4 - LCC calculations of all systems before installation (SP3),
- D4.5 - Report on "LCC calculation of all systems after installation (SP3)"
- D4.6 – Methodology for Socio Economic costs of track installation for residents.
- D4.7 – Application report on "Socio-economic costs of track installation for residents at validation sites (SP3)"