ASSET MANAGEMENT OF ROAD INFRASTRUCTURE IN THE NETHERLANDS: A FRAMEWORK FOR AN INTEGRATED LIFE CYCLE MODEL

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Abstract

It is a well known fact that transport infrastructure is vital to economic well-being of a nation. And today companies (active in highway construction and management business) face many challenges such as matured networks, increased accountability and public expectations. To cope with these challenges, we see a worldwide trend towards a more structured approach to the management of road assets.

Asset Management is a business process and a decision-making framework that covers an extended time horizon, draws from economics as well as engineering, and considers a broad range of assets. The Asset Management approach incorporates the economic assessment of trade-offs between alternative investments options, and uses this information to help make cost-effective investment decisions.

The recent years the bigger principals within the Netherlands are changing their policy for offering contracts. More and more DBFM (Design, Built, Finance, and Maintain) and performance based (maintenance) contracts lead up to a fast changing business landscape.

The objective of this paper is to introduce an Asset Management approach with special concentration on introducing a framework for an Integrated Life Cycle model and justify its need for the Dutch road infrastructure market.

1. INTRODUCTION

Efficient, economical, and safe movement of people and goods by various transportation modes is critical to the society in meeting its goals toward economic progress and social welfare.

Each year, a major share of private/public sector investments is made to protect, run, and construct transportation infrastructure. Population growth combined with socio-economic development have led to a steady increase in travel demand, which has in turn led to accelerated deterioration of physical highway asset conditions and increased concerns over congestion, safety, and the environment. Consequently, there has been an increased pressure to upgrade physical asset conditions and to improve system operations.

Responding to these challenges, transportation companies nationally and worldwide are increasingly adopting asset management concepts that identify needs of the entire highway system and strategically determine optimal investments in a proactive manner.
Asset Management is “a systematic process of maintaining, upgrading and operating assets, combining engineering principles with sound business practice and economic rationale, and providing tools to facilitate a more organized and flexible approach to making the decisions necessary to achieve the public’s expectations.” (International Organization for Economic Cooperation and Development)

The objective of this paper is to introduce an Asset Management approach with special concentration on introducing a framework for an Integrated Life Cycle model and justify its need for the Dutch road infrastructure market. Section II of this paper contains facts about the Dutch Highway Network and the current business scenario for Highway & Transportation department of Grontmij Netherlands B V with our Asset Management approach. Section III explains LCA and LCCA concepts (that are the theoretical background for the proposed framework) with their advantages and disadvantages. In section IV, the Integrated Life Cycle framework is presented with proposed implementation steps And lastly the paper concludes in section V under Observations and Recommendations.

2. BACKGROUND INFORMATION

Dutch Road Network - The Netherlands has one of the most dense highway networks in the world. There are 136,827 km of public roads of which 5,076 km are national roads, 7,836 km are provincial roads, and the remaining are local and other roads (CBS 2009). In addition, approximately 3000 bridges, culverts and other structures are embedded in the network. The Netherlands has a motorway density of 57.5 kilometers per 1,000 km², the most dense motorway network in the European Union. Since 1991, only 100 kilometers of motorway have been constructed in the entire country, of which only 26 km lie within the Randstad (which includes Amsterdam, Rotterdam, The Hague, Utrecht and surrounding area) metropolitan. The population has grown by 1.5 million since, creating significant congestion issue on the motorway network. Congestion costs were valued at 0.6 billion euros in 2002 and is estimated as high as 1.7 billion euros by 2020 (RWS AVV, 2004)

Asset Management – The concept of Asset Management has been around for many years now, changing shape and emphasis to include changes in the operating environment. In the 1980s, the focus was more on the construction of new assets with maintenance & management of existing assets being a low priority (Mihai et al, 2000).

Recently, with increasing demand the focus has changed to maintenance and life extension with highway agencies being held more responsible and has to be cost effective to be in the market. This can be seen as Rijkswaterstaat (a part of Dutch Ministry of Transport and Public Works) that is responsible for construction of highways and waterways and their maintenance in the Netherlands is increasingly asking market players to take the responsibility for preparing designs. The client’s responsibilities are focused on formulating specific requirements that the designs must meet and on monitoring these requirements during the design and construction process. Also, the market sees a large number of maintenance contracts from the Rijkswaterstaat (RWS) coming along the way. With the changing business scenario, the Service Level Contracts might become standard, in which contractors will be responsible for the availability of larger parts of the network. Public-Private Partnerships (PPP) will become more common; as per RWS’s website already some pilot projects, like the A15: broadening of Maasvlakte - Vaan Square project and the second Coentunnel project are under progress and more PPP’s are being initiated. The relationship between contracting authorities and contractors will shift in the coming years towards a partnership based upon equality, rather than authority. PIM (Partner Programme for Infrastructure Management)
explored this new paradigm in the last few years, both within the programme as well as on the work floor in the primary process through different pilot projects with Grontmij as a partner amongst others. All this will mark a transition from traditional method of contracting and solely technically oriented performance specifications to contractors’ playing a larger role and specifications that are more directly related to the interests of road users and the public. To handle these challenges, we have recognized certain key concepts in our asset management approach (figure 1).

![Grontmij Asset Management Approach](image)

One such Asset Management concept (as seen in figure 1 at tactical level), which is our current focus, is Life Cycle management.

Life Cycle Management (LCM) is the application of life cycle thinking to modern business practice, with the aim to manage the total life cycle of an organization’s product/services towards more sustainable consumption and production (Jensen & Remmen, 2004). LCM is the umbrella concept that integrates a variety of fundamentals, methods and tools from qualitative (life cycle thinking) to quantitative tools (like Life Cycle analysis, Life Cycle Cost Analysis etc.).

The following section will describe these Life Cycle tools.

3. **LIFE CYCLE TOOLS**

3.1 **Life Cycle Analysis**

As per NEN-EN-ISO 14040:2006, LCA is defined as the “compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.”

In other words, LCA enables the estimation of the cumulative environmental impacts associated with a product/service resulting from all stages in its life cycle. It is also known as ‘Cradle-to-Grave’ analysis.

LCA had its beginning in the 1960s, when the Coca Cola Company funded a study to compare resource consumption and environmental releases associated with beverage containers. In recent years life cycle thinking has become a key focus in environmental policy making. A clear example is the concept of IPP (Integrated Product Policy) as communicated by the EU and further east the Circular Economy concept in China (SAIC, 2006). LCA provides the scientific basis for all these new concepts.

As per NEN-EN-ISO 14040:2006, there are four phases in a LCA study:
1. Goal and Scope definition phase.
2. Inventory Analysis phase (or Life Cycle Inventory, LCI).
4. Interpretation phase.

3.2 LCA in practice

Traditionally, decision-makers make their decisions based upon only economic benefits and the environmental aspects are often not considered but lately companies are rushing towards LCA application because of drivers like, brand value enhancement, Legislative requirements (like IPP) and changing market conditions.

Based on the mentioned driver, continuous scientific endeavors and technological advancements, companies around the world are capable to perform LCA involving vast multitude of input data using the following ways:

1. Using a spreadsheet. Beneficial only when dealing with small product/service system.
2. Using a dedicated LCA program. There are many such software available in the market today like GaBi (by PE International, University of Stuttgart), SimaPro (by Pre Consultants, The Netherlands), CMLCA (created by Centre of Environment Science, Leiden University, The Netherlands) etc.
3. One can also decide to develop his own program. Although it gives a lot of scope for customization but requires a lot of expertise and resources.

3.3 Major advantages and issues with LCA

Performing LCA gives benefits like the danger of problem shifting from one life stage to another can, in principle, be avoided because LCA takes whole life cycle into account. In addition, consumers attitude towards companies are positively influenced by an active environmental policy. Thus, it can be used as a tool for marketing. Overall, use of LCA helps in improving the image (and goodwill) of a company.

As with any model, LCA has its share of disadvantages like performing a LCA is resource and time intensive, unlike ISO9001 and ISO14000 standards, it is not possible to get an official accreditation for any LCA methodology or software. Thus, there is no worldwide standard system for practicing LCA. LCA cannot address to localized impacts & risks due to underdeveloped databases.

3.4 Life Cycle Cost Analysis

"It’s unwise to pay too much, but it’s foolish to spend too little.”

This adage by John Ruston can be considered as the operating principle of Life Cycle Cost Analysis.

Life Cycle Cost Analysis (LCCA) is defined in the Transportation Equity Act for the 21st Century (TEA-21) of US Federal Highway Authority as "a process for evaluating the total economic worth of a usable project segment by analyzing initial costs and discounted future costs, such as maintenance, user costs, reconstruction, rehabilitation, restoring and resurfacing costs, over the life of the project segment."

The concept of LCCA was first discussed in the 1960s in the AASHTO “Red Book” (Wilde et al 2001). Thus, the concept is not new but underused in Construction industry (Bull 1993)

As per US-FHWA, the following steps are involved in conducting the LCC Analysis:

1. Establish alternative pavement design strategies for the analysis period.
2. Determine performance periods and activity timing.
3. Estimate agency costs.
4. Estimate user costs.
5. Develop expenditure stream diagrams.
6. Compute net present value.
7. Analysis of results.
8. Reevaluate design strategies.

3.5 LCCA in practice

In the US since the early 1990s, FHWA has encouraged a policy of encouraging the use of LCCA for transportation decision. Many states’ Department of Transportation (DOTs) have incorporated LCCA in their respective pavement selection method (Chan, 2007). As with LCA, LCCA can be performed: Using an Excel spreadsheet function; Using dedicated LCCA software. Many such software solutions are available in the market today like RealCost (developed by US FHWA, USA); and finally when an organization has developed the expertise, they may decide to develop their own specialized software.

3.6 Major advantages and issues with LCCA

Some main benefits of performing LCCA are: it uses familiar unit, money, in calculation making it is easy for decision-makers to evaluate options. Next, because LCCA takes whole life cycle perspective, road managers can more reliably assess alternative preservation strategies and thus promotes innovation. Finally, in a typical organization, accounts department only wants to maximize projects NPV, maintenance engineer’s only criteria is to minimize repair costs while the stakeholders want to increase wealth. With the whole life cycle perspective, LCCA helps resolving these internal conflicts within an organization. Just like LCA, LCCA has set of issues such as LCCA is data sensitive and thus the result depends largely on quality of input data. Although transportation companies do collect data of their assets and its repairs, but specific data for example, long term maintenance data may not be directly available. Also, LCCA is a tool for comparing alternatives and it is not a tool for budgeting. And finally, LCCA does not tell the whole story. In the decision making process of project undertaking, LCCA is just one factor.

We find that, both tools have their merits and demerits and also a lot of research is being done to make them more robust. Yet, both these tools separately give an incomplete picture. In the next section, we will propose a framework for an Integrated Life Cycle model which will respond to all facets of sustainability and justify its need in the Dutch road infrastructure market.

4. FRAMEWORK FOR AN INTEGRATED LIFE CYCLE MODEL

As we understand from the previous section, LCA is useful in evaluating environmental attributes it does not provide economic information thus, making it inconclusive. On the other hand, LCCA with its monetary value do give the economic information but it fails in providing environmental and societal attributes thus, making it incomplete.

Further, researchers found that approximately 80% of the life cycle cost of the system is committed at the design (acquisition) phase while the actual cost of design activities is only around 10-20% of system’s life cycle cost (Fabrycky & Blanchard, 1991). Infact, the cumulative committed life cycle costs increases rapidly during the preliminary design phase, while the potential for life cycle cost saving is maximum at this stage it reduces sharply as we move to the operational phase that is construction, operation, maintenance and final disposal of the asset (Sullivan, 1997). Due to this strategic importance of working from the conceptual...
stage, companies have the potential to manage the design and also the responsibility for providing a sustainable solution.

In addition as cited earlier, Rijkswaterstaat is changing and as per RWS Agenda 2012, the agency plans for a higher focus on user demand. An internal working group is set up that is working on the plan of implementation of Life Cycle Costs for RWS infrastructure (RWS Implementation plan LCC, 2009). The agency is also promoting the use of LCA as an awarding criterion (RWS Criteria for sustainable procurement for roads, 2010). In addition, as per RWS’ website, Dubocalc (a software program based on LCA that calculates that calculates environmental impacts of material and energy infrastructure works) will be ready this year for use. Further, with the Roads to the Future program (Wegen naar de Toekomst, WnT), the agency is promoting innovation in technology and material for achieving more sustainable solutions. With the mentioned developments, it is clear that the concept of LCM (and tools) is here to stay and a proactive approach in identifying and including an integrated model under standard business approach will become imperative.

Finally, since an integrated model will address all 3 pillars of sustainability it is likely to bridge the gaps between government, businesses and the public providing validity and acceptance at all levels of the society and boosting a strong sustainable growth. Thus, a comprehensive tool considering all elements of sustainability -economic, social and environmental – would serve well as a method to evaluate project options.

We now present the framework of Integrated Life Cycle model.

![Figure 2: Framework for Integrated Life Cycle Model](image)

The proposed Integrated Life Cycle Model (figure 2) is adapted from Global Methodology for Life Cycle Sustainability Analysis for Construction. The framework consists of 4 modules (Agency cost, User Cost, LCI, LCIA), 3 analyses (LCCA, LCA, and Social-LCA) and 1 overall assessment.

The first step in application of this framework is development of a central database. As seen from the figure 2, user cost, societal impact score, LCI and LCIA modules are calculated with the help of this database. Most of LCA based software has their own database however
there is currently a lack of access to general, publicly available databases. (UNEP/SETAC 2005) We propose a further in-house development of the same based upon previous projects and engineering knowledge.

There are a lot of LCA/LCCA software tools available in the market today, the main problem is that most of these tools are not linked with CAD (computer aided design) software causing a time and money consuming effort at planners’ end (Neuberg et al, 2003). Thus a QA (Quantity Analysis)/CAD application is proposed for efficient calculation of Agency cost module.

Even though, user costs are considered under LCCA, still not all aspects of societal impact of a project can be taken into account using it. Thus, a tool to assess the overall societal impact of the project is required and this in turn will complete remaining dimension of sustainability.

A Social Life Cycle Assessment (S-LCA) is a social impact (and potential impact) assessment technique that aims to assess the social and socio-economic aspects of a product/service and their potential positive and negative impacts along its life cycle (UNEP Publication, 2009).


Once all three scores (LCCA, LCA and S-LCA) are calculated, a Multi-Attribute Decision Analysis (MADA) should be conducted to get the overall score. MADA is suggested because it uses qualitative as well as quantitative measuring scales to resolve problems with multiple value systems and objectives, which cannot be easily quantified (e.g. environmental impacts from LCA) and/or translated in monetary terms due to their intangible nature (e.g. social impact from S-LCA). For example, New Approach to Appraisal (NATA), a MCA based tool developed by Department of Transport, UK in 1998 for assessing transport projects and proposals based on 5 high level criterions (namely, economy, safety, environment, accessibility and integration) as identified by the government (DETR 1998). In the Netherlands, the AMW 1.1 (Afwegingsmodel Wegen) developed by the National Information & Technology department for Transport, Infrastructure and Public Space (CROW) Netherlands, is a Microsoft Excel based multi-criteria decision support Model for Road Pavements that take into account various factors such as costs (including maintenance), environmental impact, ecological value and landscape impact (CROW 2005). The assessment will give an overall score that can be used to compare the alternative designs to get a consolidated result (covering all aspects of sustainability) and thus more informed decision can be made for long term profitability and optimization.

4.1 Proposed Implementation Steps

For implementation of the ILC framework, we propose the following implementation steps:

1. LCM team: The first step toward application of Integrated Life Cycle Model is building a dedicated taskforce (at various level of the organization) with clear roles and responsibilities. The UNEP/SETAC Life Cycle Initiative suggests the following “entry gates” for implementation of Life Cycle Management: upper level of management, marketing department, R&D division.
2. **Life Cycle Thinking:** The next step is to encourage Life Cycle thinking and providing education. To achieve this, development of training material through in-house programs, manuals and certified (university) courses is required.

3. **Database:** As cited earlier, there is a demand for developing a coherent and more comprehensive database. Many commonly used softwares like GaBi (by PE International, University of Stuttgart), SimaPro (developed by Pre Consultants, The Netherlands) etc have established databases. Also, Dubocalc (developed by RWS) has a database LCI data for construction materials used for civil works. In addition, many countries like Germany, Italy, Switzerland, USA, Japan etc. have national LCI databases (UNEP/SETAC 2005). Since, the available databases cannot completely cover the localized effects; we also propose to develop in-house databases based on experience and knowledge in the organization.

4. **Product orientation and development:** Once a reasonable database is prepared to put Life Cycle thinking into actual practice, the objective should be to orient towards development of the operational model and a reporting methodology.

5. **Pilot Project:** Having successfully built a product (a complete functional ILC model) the next step is run a pilot project and test the results.

### 5. OBSERVATIONS AND RECOMMENDATIONS

The extended perspective of LCM gives rise to large scope of further research. A lot is already being done in the field of integration of the Life Cycle tools for achieving a robust and consolidated solution. In addition, many models and software solution currently exist. For example, the LCCA+ model which in addition to calculating conventional life cycle cost incorporates the value that the customer attaches to the performance and feature of the product/service (Veeffind, 1999). Life Cycle Environment Cost Analysis (LCECA) which includes the eco-costs in the traditional LCCA model (Senthil et al, 2001). PaLATE (Pavement Life Cycle Assessment tool for Environmental and Economic Effects) is an Excel based tool developed by University of Berkeley, USA for life cycle assessment of environmental and economic effects of pavement and roads. BenReMod (Beneficial Reuse Models) of LC assessment and MADA developed by University of Toledo, USA is a web based tool for comparing and ranking different alternatives for pavement construction from different materials using LCA and MADA concepts.

To sum up, this article presented a framework for an Integrated Life Cycle Model and also proposes steps required for its implementation. The framework combines the advantages of both LCA and LCCA methodology and takes a holistic view towards choosing a project alternative considering all facets of sustainability.

Development of database requires co-operation of many specialist at various levels both within and outside the organization and the contribution needs to be integrated to form a consolidated database. S-LCA concept is currently in the development stage and requires further investigation. Also a customized multi-attribute decision analysis methodology should be developed based on knowledge and experience. The proposed implementation steps are just a starting point and further research and internal studies should be done for developing a detailed execution plan.

Finally, a functional ILC model will be a ‘one stop shop’ for all sustainability issues and will enable designers, engineer, pavement manages and decision makers to make an informed and transparent decision.
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