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Abstract - Building a common transport in own site is a heavy investment. The average cost of a tram (French type) is 24 million euros per kilometer of track. More researches are interested in the optimization of this cost to allow small towns to equip themselves with this means of transport, but also to large metropolises in the South with very limited means. This is in order to respond to the major urban transport problems and the reduction of greenhouse gases.
We have discussed in previous articles the integration of BIM into railway projects [1] and we have dealt with a case study [2].In this paper we will study the cost structure of a tram throughout the life cycle. We will then proceed to a theoretical analysis of the optimization that the Building Information Modeling BIM can bring to the cost of a tramway project.We will also highlight in this paper the results of research on the integration of BIM into railway projects by showing the benefits and trends of adoption.
This study hopes to open the door to industrial applications and promote the integration of BIM in tram projects. During the discussion of the results, we will propose future research tracks in this theme, including the possibility of studying a real case.

Keywords - Building Information Modeling, Tramway, cost, optimization, integration, BIM.

INTRODUCTION AND METHODOLOGY

Feedback from several tramway projects around the world estimates the cost of the tram between 18 and 38 million euros per kilometer of track. Indeed, Jesus Gonzalez-Feliu [3], in a study of freight tram in Paris, estimated this investment at 22 million euros per kilometer. Millet [4], for the initial loop of the Montreal tramway, puts forward a budget (in 2008) of 1248 million Canadian dollars for 21.9 km of network, which amounts to (1 Canadian dollar = 0.66 euro) to 37 , 61 million euros per kilometer against 32.31 originally planned according to the same source. In Morocco, Casa Transport (manager of public transport network in own site, Casablanca) estimated to the press [5] in 2012 the cost of the first tram line of Casablanca to 5.9 billion dirhams for 31 kilometers which amounts (11dirhams = 1 euro) to 17.3 million euros per kilometer. A report [6] by Urban Transport Group (produced by Egis Semaly&FaberMaunsell) estimated costs per kilometer of tramway (cost in 2003) as follows: Lyon T1 + T2 at 19.49 million euros, Strasbourg B to 22.62 million euros.

Of course, the cost of a tram depends on several factors: design choices, geographical and geological data, frequency, cost of labor, number of stops, etc. A French association "L'Atelier du Tramway" [7] "supports that it is possible to make a tram at 14.5 million euros per kilometer against 24 million on average ". The association takes the example of the Besançon tramway where “we managed to limit the bill to 17 million euros per kilometer". "We have to consider the savings on the initial investment, but also on the operation." If we accept a deteriorated operation episodically, this would generate minimal disruption of the network and we would substantially lower the costs"said the president of the Association. In any case, the cost of tram is expensive for small agglomerations, and even for large agglomerations in developing countries. The cost optimization tracks, currently under study, are multiple and concern several factors: optimization of the design, degradation (in the acceptable limit) of the operating level (example of the "L’Atelier du tramway" association), suppression of certain functionalities, optimization of operating and maintenance costs, ...

In this paper, we have chosen to do a theoretical analysis of the optimization of the cost of a tram by integrating the Building Information Modeling BIM from the sketching phase and throughout the life cycle of the infrastructure. The methodology adopted is to first make a review of the literature to make a decomposition of the cost of a tram and fix the sub-costs on which we study the optimization contribution that the integration of BIM can bring. Then, we will move to a theoretical analysis based on the empirical results realized or projected on real projects to estimate the possible savings following the integration of the BIM.

The aim is to provide the theoretical basis for optimizing the cost of a tram in order to promote the integration of BIM in tramway projects, and in railways in general.

Cost Structure of a Tram - Assumptions fixed for the Analysis.

There are several forms of tramway. We will consider the tramway as public transport, generally urban, steel wheels running on railways, in own site, equipped with rails, and which is installed with electric traction powered by a catenary (overhead contact line).Forms of trams appeared at the beginning of the eighteenth century before disappearing after the two world wars [8] [9]. Modern trams (object of this study) will have a second life from the 1970s.

Cost Structure of a Tramway - Construction Phase: Comparative Analysis.

We have chosen as a basis for decomposing the cost of a tramway the decomposition of CERTU (Center for Studies on Networks, Transport, Town Planning and Public Construction - France) [13] given by Laborde [12].This decomposition is based on the following items:Preliminary studies - Project management - Project management - Land acquisition and release of rights of way - Deviation of networks - Preparatory works - Structures - Platform - Specific track of the rail and guided systems - Pavement of the clean site - Road and public spaces - Urban equipment - Road signs - Stations - Electrical substations and overhead contact lines - Low current and central command post - Depot - Rolling stock.

Our search for the costing of each item led us to compare three projects: a tramway project of the "L'Atelier du Tramway" association, the Besançon tramway and the Caen tramway. This comparison of the cost decomposition is shown in the following table:

	Egis / Atelier du Tramway [10]	Tramway Besançon [11]	Tramway Caen [12]
Preliminary studies	2%	0,50%	2%
Project owner management	6%		7%
Mastery of work	7%	6%	3%
Land acquisition and release of rights of way	2%	7%	0%
Deviation of networks	3%	5%	0%
Preparatory works	3%		1%
Structures	2%		3%
Platform	3%		6%
Specific track of the rail and guided systems	13%	34%	22%
Pavement of the own site	4%		6%
Road and public spaces	10%	11%	5%
Urban equipment	2%		1%
Road signs	1%		2%
Stations	2%		3%
Electrical substations and overhead contact lines	9%	30,50%	2%
Low current and central command post	6%		5%
Depot	7%	6%	11%
Rolling stock	18%		22%

Table1: Comparison of the costs of tramway projects - construction phase.

Hypotheses made for the fixed and studied sub-costs in construction phase.

We saw in the previous paragraph the construction costs of construction of a tramway, the reference decomposition. We voluntarily chose, for the purposes of this analysis, to fix the costs related to the rolling stock and those of the project owner (including land release and acquisition costs). We also took an average of the costs for each heading, as we grouped the headings to facilitate the analysis.

	Egis / Atelier du Tramway [10]	Tramway Besançon [11]	Tramway Caen [12]	Average taken by authors
Engineering & Mastery of work	9%	7%	5%	7%
Land acquisition & project owner management	8%	7%	7%	7%
Civil works including rail	40%	50%	45%	43%
Systems	18%	31%	11%	15%
Depot	7%	6%	11%	8%
Rolling stock	18%	0%	22%	20%

Table2: Summary of the construction cost structure of a tramway.

Therefore, the fixed costs (in the sense of our study) represent 27% of the cost of construction and represent the costs of the owner of the project as well as the rolling stock. In this hypothesis, we consider that the Building Information Modeling has no contribution of cost optimization relative to the project owner (search for financing, administrative procedures, release of land, ...). We have also assumed the cost of rolling stock, which means that the analysis of BIM's relationship to this industry is part of another research theme. The costs we are going to study represent 73% of the cost of building a tram and concern: the infrastructure, the platform including the rail, the energy and low current systems, the maintenance depot, etc.

Cost of Facility Maintenance

Laborde [12] estimates that the costs of major maintenance (discount calculation at 4.5%) is estimated at 0.60% of investment annually (excluding rolling stock), which equals 18% over 30 years (duration of the depreciation of the investment).According to the estimates in the previous paragraph, the cost of maintenance (excluding operating costs and associated personnel) is 18% multiplied by 66% (percentage of infrastructure studied outside of studies). This means that maintenance costs 11.88% of the initial cost of the initial overall investment.The cost of maintenance is sensitive to several parameters [14]: number of shuttles, mileage traveled, number of passengers, fixed costs of the operator, etc. For the model built by Xinmiao [14] and for the reference project,

maintenance is 23% of the overall cost of the infrastructure investment (66% of the initial cost of the overall project), which is 15.8% of the original project cost.A recent study in Croatia [15] estimates that the maintenance of an infrastructure represents half of the initial investment (in other words 33% of the initial cost of the entire project).For the purposes of the following analysis, we take an average cost of maintenance of fixed installations at 14% of the amount of the overall initial investment of the project.

Summary of Costs Studied - Basic Hypotheses of the Analysis.

For the rest of the analysis in this paper, we consider a tram construction project of 15km length, with a maintenance depot. We consider the average of 24 million euros per kilometer as the cost of construction.This gives a direct investment for the realization of the project of the order of 360 million euros.In this case, infrastructure (including design and studies) represents 73% of the amount invested, or 262.8 million euros. The rest (rolling stock and costs of the project owner) is fixed.In the same logic, the maintenance (over 30 years) costs 14% of the initial amount of the investment, i.e. 50.4 million euros.

Optimization of cost of a tram through the integration of BIM: A theoretical analysis Theoricalanalysis of cost optimization.

We will study through the literature the possible optimization of the costs of a tramway by integrating the BIM from the beginning of the construction project and throughout the life cycle. Through the literature [1] [2], the cases studied [15] [16] [17] [18] [19] [20], we have constructed the following table:

Phase	BIM benefits	Cost impact of using BIM	Results and comments
Idea	Concept, Feasibility, and Design Benefits		
	Increased Building Performance and Quality		
	Improved Collaboration Using Integrated Project Delivery		
Design	Earlier and More Accurate Visualizations of a Design		
	Automatic Low-Level Corrections When Changes Are Made to Design		
	Generation of Accurate and Consistent 2D Drawings at Any Stage of the Design		
	Earlier Collaboration of Multiple Design Disciplines	reducing 15% change orders	Change orders estimated to 10% of project costs. This corresponds to 1.5% reduction of the cost of construction
	Easy Verifi cation of Consistency to the Design Intent		
	Extraction of Cost Estimates during the Design Stage		
	Improvement of Energy Effi ciency and Sustainability		
Construction and Fabrication	Use of Design Model as Basis for Fabricated Components		
	Quick Reaction to Design Changes		
	Discovery of Design Errors and Omissions before Construction		
	Synchronization of Design and Construction Planning	reducingg 5-15% schedule	10% reduction of time corresponds to 5% reduction of the cost of construction of the project (50% of the cost of the projects are relative to manpower, management and machinery)
	Better Implementation of Lean Construction Techniques		
	Synchronization of Procurement with Design and Construction - reduction of wast & reworks	saving 9% of materials	This corresponds to a 4.5% reduction in the cost of construction
Post Construction Benefits	Improved maintenance process	Saving 10% of cost	
	Improved Commissioning and Handover of Facility Information		
	Better Management and Operation of Facilities		
	Integration with Facility Operation and Management Systems		

Table3: measured benefits of integrating BIM totram construction and operation project.

SUMMARY

The literature and the case studies cited believe that the integration of BIM could reduce the costs of a tramway as follows (as a% of the initial construction cost studied in the previous paragraph):

- 1.5% in terms of reduction of change orders.
- 5% in terms of reducing the overall construction time.
- 5% in terms of wast material & reworks reduction.
- 10% of the maintenance cost corresponding to 1.4% of the construction cost.

In summary, the integration of BIM into a life-cycle tramway project saves 8.4% of the overall project cost, which is equivalent to saying that the cost can be reduced to 21.98 million per one kilometer of tramway.The cost of constructing the 15 kilometer tramway of our reference project will then be 330 million euros instead of 360.The cost of maintenance over 30 years will be reduced from 50.4 million euros to 45.

DISCUSSION AND ANALYSIS

Using BIM in AEC (Architecture, Engineering & Construction) industry helps to reduce waste, saving 15% to 45% of materials used, conclude Shen-Hua in his thesis [21]. If we consider the reduction of waste to an average of 30%, and if we consider the waste representing 37% of the material used (Estimation of the report of the UK government), in addition, we have taken the hypothesis that the material represents 50% of the price of the infrastructure studied, the reduction thanks to the BIM represents 5.55% of the cost of the infrastructure (73% of the cost of the project), and 4.05% of the overall cost of the project. A recent study about using BIM for Estimating and Scheduling [22] estimate that material pricing using BIM help to save 15% comparatively to "traditional"

method. The reduction (in material) thanks to the BIM represents 5.48% of the overall cost of the project. These findingsare in line with the theoretical analysis above, witch estimate the reduction of cost to 5%.

Azhar [23] reported in a paper that a study of "Stanford University's Center for Integrated Facilities Engineering" gathering data from 32 major projects, estimated a savings of up to 10% of the contract value through clash detections, and up to 7% reduction in project time.These findingsare in line with the theoretical analysis above.

LIMITATIONS

The results obtained in this theoretical analysis are consistent with several limitations:

- The construction of the price of a tramway remains volatile. It depends on several factors and choice of projects. In this sense, it is indicative.
- Estimates of cost savings by integrating BIM remain highly theoretical, based on literature and case studies in the AEC industry.
- Some items were not quoted. Either by lack of data or by their nature (Example: improvement of the quality of the infrastructure).
- This theoretical analysis needs a real case study (or even several cases) to confirm it.

CONCLUSIONS – PERSPECTIVES

In this paper, we dealt with a case of construction of a tramway. We first reviewed the literature to build a cost of a tram. This price construction is dependent on several factors (length, number of stations, technical choices, ...), but we tried to converge towards an average. A typical tramway (15 km of track plus a maintenance depot) would cost 24 million euros per kilometer of track. We then set the costs related to the rolling stock (subject of a separate study) and the costs of the owner (mobilization of land, administrative management, ...). The remaining infrastructure costs (platform, railway, urban development, energy, low current, depot, etc.) represent 73% of the cost of the tram construction project. We also estimated maintenance costs (excluding rolling stock) at 14% of the initial cost of construction of the project.

Secondly, we carried out a theoretical analysis of the gains that the integration of BIM can bring to similar infrastructure projects. We crossed several sources: theoretical studies, government reports, case studies, ... This analysis showed that the BIM would reduce 8.4% of the overall cost of a tramway project, a gain of 20 million euros for the reference project. It also showed that the BIM would save 10% of maintenance costs over 30 years, a gain of 5 million euros.

During this study, or as part of other research we conducted, we identified several benefits of integrating BIM into a rail project. We have not been able to quote these other benefits and this represents one of the limitations of this theoretical analysis. Add to this the purely theoretical framework of the analysis that deserves to be confirmed by case studies, especially for a tram project to be more precise.

Current research opens the way for two major perspectives:

- Case study of a tram with the BIM to estimate the gains obtained.
- Theoretical analysis of the cost savings through the BIM for the items not quoted by this study (Quick Reaction to Design Changes, Improvement of Energy Efficiency and Sustainability, Increased Building Performance and Quality, Extraction of Cost Estimates during the Design Stage, Integration with Facility Operation and Management Systems, ...).

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