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New ropeway system for Smart Urban Mobility & Logistics in the City of Graz

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Abstract

With the need for resource-saving within urban areas it is necessary to create traffic solutions which exhibit an efficient and environmentally-friendly infrastructure system. For the first time, the research project "ROPEWAY_POT II" will identify potential for a fully-integrated goods delivery and freight logistic urban cable car system as part of "last mile" logistics for the City of Graz, taking into consideration parallel use of cable cars in public passenger transport. The project started in March 2017 and will last for 24 months. It is funded by the Austrian Research Promotion Agency (FFG). The innovative system approach offers the possibility of bundling transport of goods from the city limits over the "last mile" to shops (C2C) and clients (C2B). As a result, highly-frequented transport routes within the city are relieved and negative environmental impacts are reduced. It is also considered that further synergy effects within the overall system of goods and passenger transport may be generated. After the introduction we present the objectives, expected results as well as the procedures and methods.

Keywords: combined urban passengers and goods transport; cable car systems; last mile logistics;

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1. Introduction

Urban cable cars offer an efficient and environmentally friendly alternative in the area of passenger and freight transport compared to conventional traffic systems. Within the project “ROPEWAY_POT”, funded by the FFG, a potential analysis for passenger transport by cable cars for the City of Graz was carried out. As a result, it was established that potentials in other areas of the overall transport system may be generated. For example, the installation of a cable car as an integrated part of the public transport system leads to shifting effects away from motorized individual transport. In total, results show a potential of approximately 31,500 trips per work-day. When a conveying capacity of 3,000 persons per hour and direction is assumed, then there will still be significant capacity reserves remaining when the cable car is only used for passenger transport. This makes the targeted effectiveness of the system in operation, despite environmentally relevant advantages, difficult to justify.
Within the project “Potential for a fully-integrated cable-car for passenger transport and goods last mile chain (ROPEWAY_POT II)”, funded by the FFG, it is our aim to evaluate the possibility of shifting specific freight transport to the defined cable car system, with the close involvement of relevant partners and stakeholder’s expertise. Therefore, the requirements for such a system such as transport container size, specific transport needs and the degree of automation will be considered. Of course, also existing system solutions will be taken into account. The final logistic network will include distribution hubs, located at the city limits, cable car stations, enhanced with logistics areas, and pick-up stations for daily required goods.
In the first part of the article we present the summarized results of the preliminary project “ROPEWAY_POT”. In the second part we explain the objectives and the methodological approach in the project “ROPEWAY_POT II”.

2. Pre-project “ROPEWAY_POT”

2.1. Project framework and consortium

The project “Potential of a cable car system as an integrative part of public transport in urban areas (ROPEWAY_POT)”, funded by the FFG, was completed by the end of May 2016. The project consortium extisted of IBV-Fallast, Holding Graz - Kommunale Dienstleistungen GmbH and the Institute of Highway Engineering and Transport Planning (ISV) of Graz University of Technology. Also two well-known cable car manufacturers (companies Leitner GmbH and Doppelmayr Seilbahnen GmbH) and cable car experts (Christof Albrecht, Zatran GmbH) have been participated at the project. As a specific result within the project, the high potential of a cable car used as a public urban passenger traffic system for the City of Graz could be determined.

Figure 1: Design study of a cable car station for a cable car system within the city of Graz (zatran 2014)

2.2. Results

Within the project promising results were achieved through the implementation of a cable car as a public transport system into an existing transport model. The basis for this was a multistage mobility survey. In the first step, the travel behavior of residents could be analyzed by the results of continuous travel diaries. In the the second step, stated choice interviews delivered results concerning the behavior for usage of an urban cable car. Based on existing study results (of already realized projects), first potential estimation of a cable car solution for the City of Graz could be estimated. Especially in urban areas cable cars can be used economically and efficiently for passenger transport (Figure 2). Within a pre-project, co-executed by zatran GmbH, initial design studies on implementation of cable car stations in the cityscape could be realized (zatran 2014) (Figure 1).

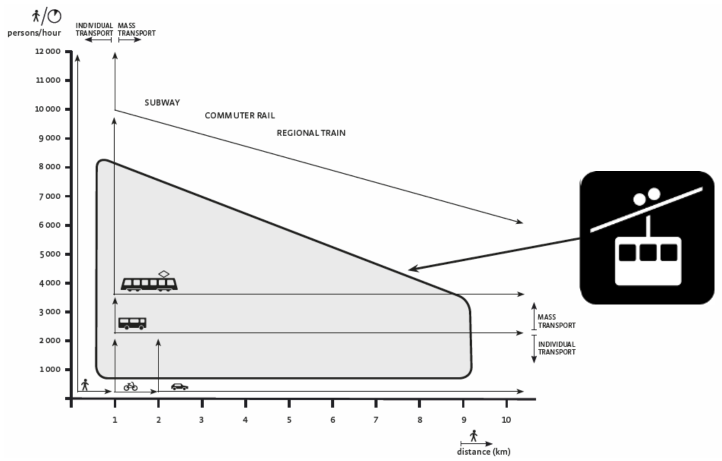

Figure 2: Typical range of application of urban cable car systems as a function of passenger volume and transport length (Seeber 2010)

Leading cable car manufacturers were involved within topic related workshops. As a result, the layout of the line, the number and location of stations and the technical data of the type of cable car system were determined. Several different scenarios have been considered (Figure 3).

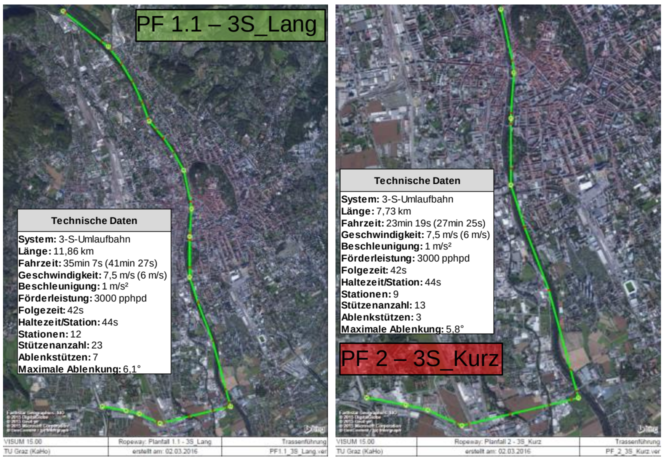

Figure 3: Two different layout variants of cable car line of an urban cable car solution for the City of Graz

Due to the regional, multimodal transport model of Greater Graz, called "GUARD", it was possible to derive the expectable hourly passenger frequency. Based on the passenger volume during the peak hour, capacity reserves were evaluated. As already mentioned, a potential of approximately 31,500 passengers per work-day may be derived (Table 1). With a conveying capacity of 3,000 persons per hour and direction, there will still be significant capacity reserves remaining.

Table 1: passenger potentials per day for different planning versions

planning version	average number of passengers per work day
3-S - Lang	30,500
3-S-Lang, PuntigamStraße	31,600
3-S-Kurz	20,500
Umstieg Lang Kombi	30,300
Umstieg Kurz Kombi	20,200

2.3. Synergies

The following research results from ROPEWAY_POT are transferred to the project ROPEWAY_POT II:

- Layout of cable car lines; Location of cable car stations
- Technical data of the cable car considered
- Calibrated transport model and hourly passenger volume
- Performance reserves within the cable car system

3. Project overview "ROPEWAY_POT II"

3.1. Project objectives

The objective of the project "Potential for a fully-integrated cable-car for passenger transport and goods last mile chain (ROPEWAY_POT II)" is to determine the potential of a combined freight and passenger cable car system as part of an urban transport system. The bundling of freight traffic into a pollution-free mode of transport from a city hub, installed at the city limit, to the city center will have an important contribution to last mile logistics and will reduce road goods traffic within the city center (Bretzke 2012). Also the last mile distribution from the cable car stations to shops or clients may be done with environmentally-friendly modes of transport (bicycles, e-vans, etc.) (Trummer 2016). Continuing on the successfully completed project ROPEWAY_POT (potential for passenger transport), basic principles of an additional innovative use of the infrastructure with modular transport systems are developed. A combination of passenger and goods transport with a detachable tricable gondola represents an innovation in city logistics.
The extensive inputs from the project ROPEWAY_POT mentioned in chapter 2.3 represent basic fundamentals for the ROPEWAY_POT II project. The extension of the cable car as a freight gondola and the implementation of pick-up stations for goods of daily needs at the cable car stations is intended to increase the attractiveness for passengers. As a result, impact on passenger potential is expected. For evaluating impact on the overall system, again all partners from the project ROPEWAY_POT are in the consortium.

3.2. Overview and expected project results

The project ROPEWAY_POT II started in March 2017 and will last for 24 months. Within the project a number of key results are defined. The following list shows a selection of these expected results:

- A *state of the art research* will be done to collect the latest concepts and knowledge on the subject of "cable cars for city logistics". The exchange of experiences with knowledge-carriers and lighthouse projects will take place.
- The transportable goods, sizes, service characterization and special requirements are defined within *service requirements matrices*. These data are defined separately according to requirements of different industries, parcel services and private users.
- Based on possible volume freight logistics being relocated from truck to cable car, saved kilometers and environmental effects are derived. The resulting *potentials of goods and passenger traffic* within a cable car system are quantified in dependence of the logistics network structure.
- A *goods and passenger traffic simulation* will be used to evaluate the achievable potentials of freight logistics, passenger traffic, environmental impacts, etc.

4. State of the art of cable cars and urban last mile logistics

4.1. Cable cars for freight transport

The use of cable cars for freight transport has a long tradition. It was only at the beginning of the 20th century that cable cars for transport of passengers were realized (Seeber 2010). The most common applications of cable cars for goods transport are:

- Mining
- Forestry and agriculture
- Factory premises
- Cable cars in alpine region

4.2. Results of state of the art research

The following listing gives a short excerpt on realized systems and planed concepts in context of urban freight cable cars and last mile logistics

4.2.1. Alternative transport solutions in urban areas

Cable car for cars, Volkswagen car manufacturing plant (Slovakia)
In the Volkswagen car manufacturing plant in Bratislava exists the only cable car worldwide that transports automobiles frequently. (source: http://autogramm.volkswagen.de/11_12/standorte/standorte_08.html)

4.2.2. Cable car concepts for urban freight and passanger transport solutions

"Wälder Bahn", Vorarlberg (Austria)
In this concept a combined passenger and freight transport system, based on a cable car system, between Bregenzerwald and the Rhine Valley (Austria) was evaluated (source: http://www.waelderbahn.at/)

4.2.3. Urban last mile logistics solutions

Delivery boxes and pick-up stations, Österreichische Post AG (Austria)
The logistics company provides its customers reception boxes and pick-up stations as additional services within last mile logistics. (source: www.post.at)

Research project NOVELOG
The project, funded within HORIZON 2020, examines the distribution of goods in urban areas. In a pilot project, the usage of cargo-e-bikes in the City of Graz is investigated.
(source: http://www.graz.at/cms/beitrag/10272002/1618648/)

5. Procedure and methods

5.1. Planning approach

In the project, a planning approach is consistently passed, which is based on three investigation levels shown in Figure 4. These levels should be taken into account in all projects for planning sustainable city logistics concepts (Pfohl 2010).

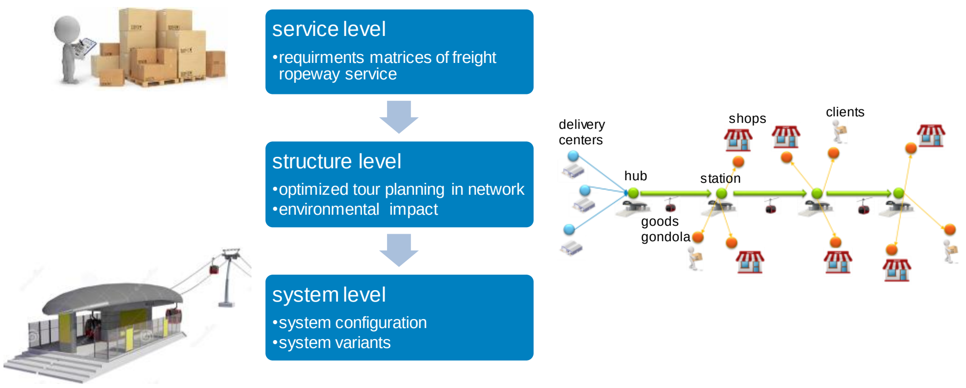

Figure 4: Consideration levels for planning city logistics concepts (clip arts: www.dreamstime.com)

Service level
Logistics services must be aligned to wishes and requirements of customers. Questionnaires, interviews and statistical surveys are used to determine the service requirements matrices for the definition of a customer-oriented logistics system "cable car for freight transport" in the City of Graz.
Structure level
The structural level refers to the material flow network with logistics nodes and logistics connections. In this level, an abstract consideration of the task is carried out in which the methods of graph theory, material flow calculation and operation research are used to optimize the network structure without dealing with specific technical implementations.
System level

The system level incorporates technical realizations into system solutions. Technical and organizational variants regarding the relevant technical systems (transport, storage, handling, etc.) are developed and evaluated, also in technical and economical manner.

Goods and passenger traffic simulation

To evaluate the obtained planning results within the project, a freight and passenger traffic simulation will be realized, using state of the art simulation software.

5.2. Detailed description of planning approach

In detail, the following contents, methods and results are obtained for the named planning approach:

5.2.1. Service level

The basic task of logistics services can be assumed as the provision of required goods in the required quantities in the right composition at the right time at the right place (6 R's of logistics) (Pfohl 2010). Within the term of city logistics, approaches are defined to bundle goods and thus make the resulting logistics services more efficient (Buchholz 1998).

In coordination with project partners, the statistical bases to be recorded are defined, considering different branches and goods classifications. The preparation of workshops takes place and characteristic parameters to be collected are defined. In cooperation with the Economic Chamber of Styria, local stakeholders, the City of Graz, private end-users and relevant local parcel service providers, specific requirements are set for the delivery services. Specific product groups as well as time, local and handling conditions are recorded. For this purpose, it is planned to integrate the user groups for deriving the service requirement matrices in different workshops. Expert interviews, including also cable car manufacturers and cable car operators, and extensive surveys summarize the fundamentals of goods flows, service requirements and shift potentials. The resulting service requirements matrices are used as inputs for further system concretization of a logistics system "urban goods cable car" (Figure 5).

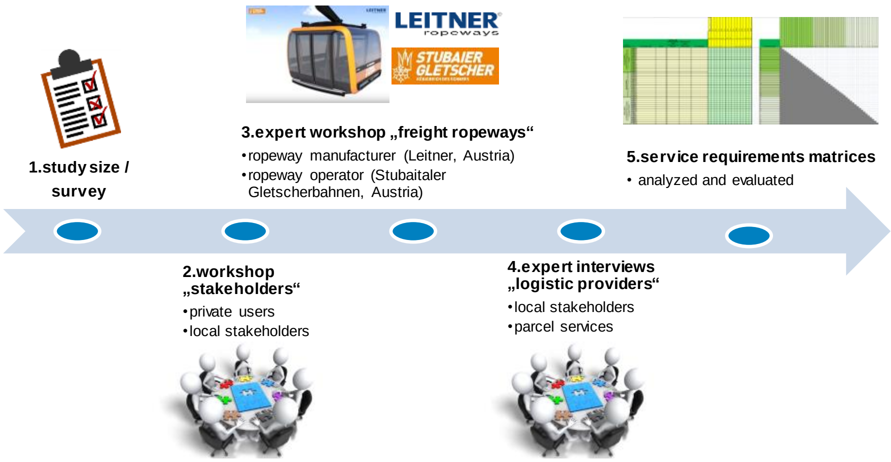

Figure 5: Procedure in project for determining the service requirements matrices (picture source: www.leitner-ropeways.com; clip arts: www.dreamstime.com)

Within the work packages, proven, standardized survey methods are used (e.g. questionnaires, interviews, statistical surveys, etc.). The content of the interviews is coordinated with the output of the workshops. Care is taken to ensure that the methods are also applicable to investigations in other cities / regions. The mentioned questionnaires for collecting the service requirement matrices are divided into several subcategories (Figure 6).

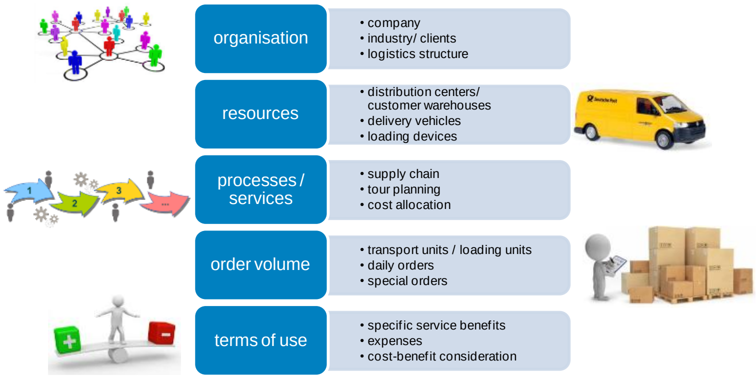

Figure 6: Structure of the survey for determining the service requirement matrices (clip arts: www.dreamstime.com)

Process diagrams are used to subdivide a complex, multi-level service process into individual, interconnected process steps. The subdivision takes place according to time, local or organizational criteria. The following process chain is defined for the handling of an urban goods cable car system. In this, the service process is divided into three main process phases (Figure 7):

- Goods receipt with goods delivery, storage and formation of transport units in logistics areas of cable car station (hub)
- Transport with loading / cinching, transport and unloading of transport units in freight gondola
- Goods issue with storage, formation of transport units and goods collection in logistics areas of cable car station (delivery station)

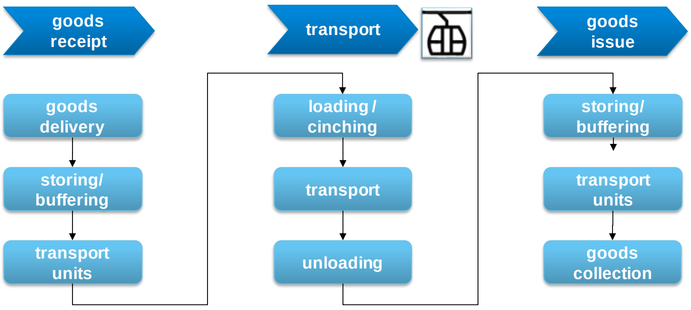

Figure 7: Process diagram for describing the processes in the logistics system of an urban goods cable car

5.2.2. Structure level

In logistics systems, different logistics processes are linked. The interaction of these processes can be represented graphically by networks. In these networks, logistics nodes (for example warehouses, distribution depots, cable car stations) are connected to one another via edges. Edges represent transport links and means of transport (road connections with trucks, cable car with gondolas). Logistical units (packets, pallets, roll containers, etc.) are moved through the network from node to node (Pfohl 2010).

By implementing a cable car system as an urban mode of transport, the resulting network is defined as a two-stage logistics system (Figure 8). Space and time is bridged by an indirect flow of goods between the delivery point (distribution center or warehouse) and the receiving point (customer or shop). At the delivery points, goods are provided (source), at the receiving points goods are used or consumed (drain). Thus, within a two-stage logistics system the flow of goods is interrupted at two points at which additional processes (storing transport, handling, etc.) take place. In these interruption points, concentration (bundling) or splitting of the product flow occurs.

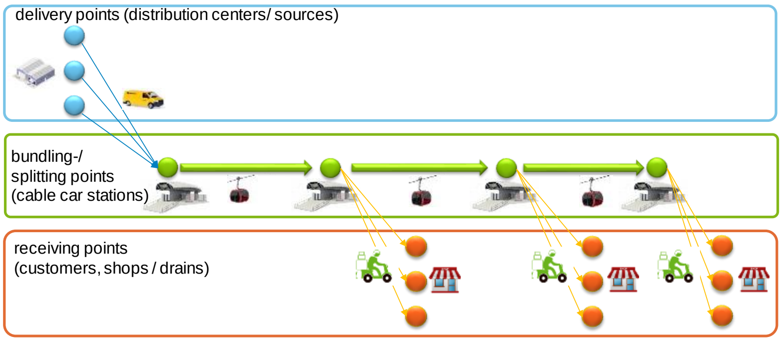

Figure 8: Resulting network of the logistics system (clip arts: www.dreamstime.com)

For planning the logistic network, methods of graph theory, operation research or material flow planning and simulation are used (Baudach 2013). Within the network the optimal network structure, minimal transport times and distances, or maximum throughput rates are determined. As a result of the planning, we get a time-, tour- or cost-optimal logistics network structures with high customer satisfaction, as a superior objective (Figure 9).

Figure 9: Concept of the network structure for an urban goods cable car system for the City of Graz (picture source: www.googlemaps.com; clip arts: www.dreamstime.com)

5.2.3. System level

The defined requirements matrices serve as input for design of several configurations of a goods cable car system. The several variants of the system differ in their technical design, capacitive limitations, degree of automation, etc. In addition, the design of the hubs and distribution stations is carried out. Furthermore, pick-up stations are located in the logistic system. As a result, system specific parameters are defined, which are available as input variables for potential determinations. For this purpose, individual processes such as loading and unloading operations, transport times and technical feasibility within the cable car system are verified.

	solution 1	solution 2	solution 3
gondola system			
technical design	standard passenger gondola	specific goods gondola	combination
degree of adjustment	without adjustment	with adjustment	
rope system			
	3 rope system	1 rope system	
station			
circulation system	common system	separate system	
circulation level	common level	separate level	
passanger/ logistic area	common area	separate area	
loading/ unloading technics			
loading	manual	semi automated	automated
unloading	manual	semi automated	automated
load carriers			
degree of automation	activ	passiv	
guiding	floor guided	rail guided	overhead guided
additional means of transport (forklift, shuttle, etc.)			
degree of automation	manual	semi automated	automated
local mapping	stationary	mobile	

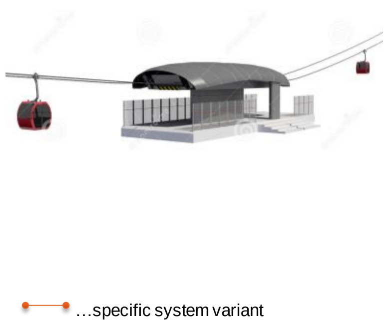

Figure 10: Morphological analyzes for a specific system variant of the cable car system (clip arts: www.dreamstime.com)

In doing so proven and standardized methods from the range of systems engineering are used (Winzer 2016). Among other things, different creative techniques such as morphological analyzes or cluster analyzes are used. Morphological analyzes serve, for example, to derive individual configuration variants of the overall system (Figure 10). Cluster analyzes can be used to determine optimal transport vessel or gondola sizes.

The conceptual design of logistics areas / logistics equipment, storage capacities and waiting areas (related to passenger transport) within the hub and cable car stations is carried out using classical methods of material flow calculation, resource and layout planning (Arnold 2007). Figure 11 shows a conceptual design of a cable car station for combined freight and passenger transport.

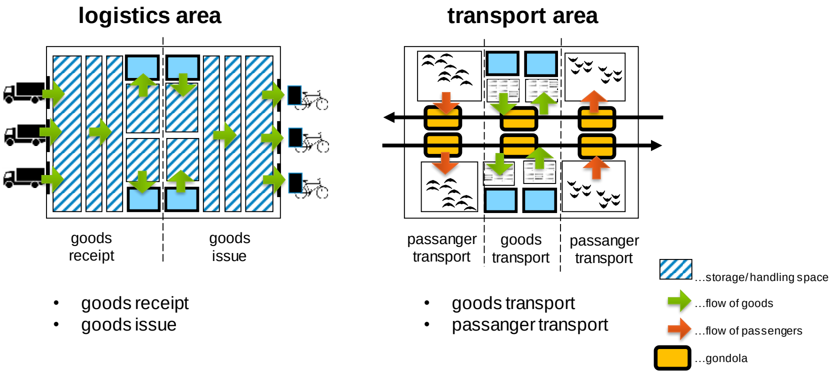

Figure 11: Conceptual design of a cable car station for combined freight and passenger transport

5.2.4. Goods and passenger traffic simulation

An important step within the project is to evaluate results from the planning procedures for plausibility. A common procedure for the verification and validation of planning results is the usage of simulation methods. Simulation means performing experiments not on the original system, but on a suitable replication (=simulation model) (Goedicke 2013).
The basis for modeling is the defined requirements matrices, which characterize the logistics system of the defined goods and passenger cable car system in detail. With the aid of defined simulation variation parameters, different scenarios for the simulation of the freight and passenger traffic within the cable car system are derived. The resulting simulation studies are intended to provide information on the quality of the planning results and to demonstrate possible optimization potentials (Figure 12).
In particular, the following results are to be investigated within the goods and passenger traffic simulation of the cable car system:

- Goods / passenger potentials for optimized system utilization
- Pricing for an economic operation of the system
- Environmental impact by shifting freight and passenger transport from road/ public transport to cable car

Within the project state of the art simulation software is used to realize the goods and passenger traffic simulation, such as the VISUM software from PTV AG for the transport model GUARD and VISSIM also from PTV AG for the microscopic traffic simulation.

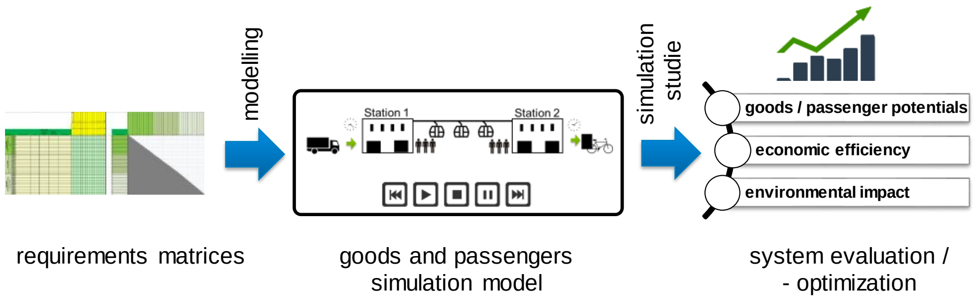

Figure 12: Procedure of goods and passenger traffic simulation to evaluate project results

6. Potentials of project results

The implementation of a combined freight and passenger cable car integrated into an urban transport system would be a global innovation. The environmentally friendly mode of transport generates synergies in its dual use. Logistics hubs and distribution centers at the city limits and/ or within the city are used in freight logistics as the basis for appropriate freight and traffic bundling. Passengers will be able to switch from park and ride areas, operating as intercity traffic connections, to public transport. Cable car stations therefore are operated as multifunctional operating points in freight logistics and passenger traffic.
Based on bundling effects and avoidance of unnecessary journeys and displacement effects in the overall system, positive environmental and social impacts are expected. Due to characteristics of certain goods (goods without critical time relevance), times of low passenger frequency can be used for freight transport and therefore the utilization of the cable car can be increased. Due to almost permanent availability of the transport system, advantages can also be achieved with regard to short-term logistics (for example medical products) and more predictable logistics. The integration of all relevant stakeholders (representatives of the sectors, authorities, private users, logistics service providers) ensures that all relevant framework conditions are taken into account.
Depending on the results of ROPEWAY_POT II and the newly created and founded foundations, new business models and research fields will open up and the development of further innovations will be promoted. In addition, it is possible to derive any necessary transport policy measures.

7. Summary and outlook

The advantages of cable cars are numerous. For this reason, they are rediscovered for modern goods transport. Environmental aspects and infrastructural bottlenecks made the cable car technology for the transport of people even in the urban area attractive. Especially in the conurbations in Latin America, there is almost a cable car boom. In Europe too, many cities are considering installing a cable car as a part of a public transport network as a connector or feeder system. Combined cable cars for the transport of passengers and goods in urban transport have not yet been conceived or realized. The same applies to pure freight transport solutions in the city. The primary advantage of cable cars in freight transport is their high efficiency, both in terms of investment and operation, compared to trucks or railways. However, a combination of passenger and goods transport with cable cars could mean an innovative approach in city logistics.

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