In consideration of the determination of the Regione Piemonte – Direzione Coesione sociale No. 1057 of 25/7/2019 which approved the following apprenticeship position for the PhD project proposal submitted by the Politecnico di Torino in the framework of a specific regional call for proposals (Apprendistato di Alta Formazione e Ricerca 2016-2018 - Avviso Pubblico per la realizzazione dei percorsi formativi di: Laurea triennale e magistrale, Diploma Accademico di primo e secondo livello, Master di primo e secondo livello Universitario, Dottorato di ricerca e Diploma accademico di formazione alla ricerca, Attività di ricerca approvato con Determinazione 537 del 3/8/2016):

PhD in Energetics

Research project "Sistemi innovativi per il trasporto urbano con trazione a fune: progettazione e consumi energetici"

Politecnico di Torino – Dimensione Ingenierie s.r.l.

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Context of the research activity	At the beginning of the 21st century, several scientific studies drew attention to the unsustainability of the **massive use of fossil fuels** as the main global source of energy and this led to international

public organisations starting numerous projects aimed at containing the resulting greenhouse gas emissions.
In this context, **rope-based or cable-driven *Automated People Movers* (APM)** can play an important role, as they are **fully automated transport systems** operating on a fixed track, along which the vehicles can be pulled by one or more steel wire ropes.
This feature makes it possible to manufacture lighter and *less energy consuming* vehicles (cabins) because of the on-board absence of propulsion, transmission and energy accumulation elements, with a consequent lightening of the structural parts. The use of electric energy to power these transport systems makes it possible to take advantage of energy sources that are *not necessarily black-oil dependent*.

An APM is a fully automated transport system, accessible to the public, that is characterised by vehicles moving on segregated ways featuring both a variable grade and horizontal layout, or tortuosity. When dealing with a cable APM, the traction of the vehicles is provided to one or several rings of steel wire rope. The speed of the vehicles has to be reducible to a null value in stations, to allow slow passengers and possible wheel-chairs to enter or exit the vehicle and goods to be loaded or unloaded.

The high level of automation of these systems allows the *"on-demand" service,* which is currently used for elevators, to be used during off-peak demand hours, when traffic is moderate. In this case, the vehicles remain available inside the stations until the service is activated by users through a dedicated button. This service mode allows further *energy savings* to be obtained.

The experience concerning the cable driven APMs is relatively limited, since the plants completed up to now are not very numerous. Nevertheless, the accumulated experience – considering also the fields of conventional rope transport systems as ropeways and funiculars - permits to trace some main principles and guide the general engineering and design of such transport systems. Their importance is nowadays much higher also because of their highly significant competitive *specific energy consumption* per passenger and per km, as there is no need to install a motor on board, and -

	consequently - neither the transmission to the wheels nor a structure suitable for the related weights, leaving the tractive power transmission to a mechanical transmission with small inertia, such as a steel wire rope. Therefore, such installations can result attractive also from the environmental viewpoint, since the engine and the relevant noise emissions can be segregated in a protected area. It is difficult to find other motorised means of transport so competitive in terms of energy consumption and noise emissions as the rope-based APM. The Company Dimensione Ingegnerie has planned for the winner of this position a collaboration within a contract of **high apprenticeship** according to the Italian Legislative Decree 81/2015, art. 45.
Objectives	In 2011, the *European Commission* drew up the so-called *Transport 2050,* in which measures to reduce the dependence on the monopoly of black oil were illustrated, and innovative solutions to contain CO_2 emissions related to the transport sector were promoted. Since the Eighties black oil and CO_2 emissions have represented one of the main causes of air pollution, besides being associated with the consumption of approximately half of the world's extracted black oil used for transportation. As far as public transport systems – so including rope-based APMs - are concerned, most of the *factors* that affect energy consumption, therefore emissions, are mainly related to vehicles, their performances and to the design of their lines, once the travelled distance or their time of usage have been fixed. These factors pertain to: – The type of the powertrain adopted for the traction of the vehicles (Internal Combustion Engine or ICE, on-board; rotating or linear electric motor, on-board; with hauling or carrying-hauling steel ropes, out-board) and for the track; – The mass of the vehicles and the inertia of the components of the system, as well as their related dimensions and aerodynamics; – Performance parameters, namely acceleration and the

	maximum speed; – The capacity and load factor of the vehicles; – Driving style, for the case in which there is a driver, not that of APMs; – *Intelligent Transport Systems* (here referring to the synchronisation of transit with traffic lights, fleet management, information supports) in the case of those public transport systems that can take advantage of ICT applications. Other aspects can also affect the energy consumption of transport systems; these essentially depend on service *scheduling*. However, these are variables that often cannot be modified significantly since they are constrained to satisfy previously defined volumes of traffic in the daytime and to guarantee an adequate or a minimum level of service. The relevant energy aspect of this project research, to be strictly coupled with the economical one (installation and operational costs), has to be been analysed using original simulation models, in which several variables, including the vehicle load factor, can be considered. The results, expressed for example in terms of *energy consumption/(pass·km)*, are expected to be comparable with the specific energy consumption of alternative urban transit systems, according to the most recent technical literature.
Skills and competencies for the development of the activity	The candidate shall be **less than 30 years old** at the moment of the hiring from the company. The **skills of the candidate** imply competences in the: - **Energy engineering** area, as far as efficiency is concerned (we may quote, as an example, energetic analyses made on the base of *well-to-wheel*, *well-to-tank* ad *tank-to-wheel* besides on specific energy consumption of different transport means, as kWh/pax·km or gep/pax·km, gep[1]/t·km), - in the engineering, design and operation of **transport systems** (Mechanical, Energetics and/or Civil Engineering) and in the **management engineering**.

[1] *gep* stands for *equivalent grams of petroleum ("grammi equivalenti di petrolio"), which is a measurement unit for energy consumption; 1 gep ≈ 5.35 Wh.*

According to the profile of the winning candidate, any lack of competences on the abovementioned profile shall be filled in with the **ad-hoc educational or training path** within the Ph.D. course.

The **tasks** of the Ph.D. student will then be:

- to complete his skills through classes and specific courses to be chosen with the academic tutor as well as attending seminars and conferences (at national and international level) to be decided also with the Company;
- to investigate, also through practical tests, simulations and prototypes, the above-mentioned objectives through the design and the analysis of components, concept architectures and operative modalities, energy consumption and failure and risk analysis of rope-based APM;
- to perform all the relevant energetic analyses;
- to perform all the relevant economic analyses;
- to publish approximately four or more articles on ISI journals during the three years of contract.
- to manage relationships with national and international partners in the field of the described research project.

At the end of the apprenticeship the candidate will hold a Ph.D. in Energetics, specializing on transport systems, with mature professional skills in the field of innovative urban transport systems based on rope technology, and a complete formation about their energy consumptions besides some economical outcomes.