Supporting the Planning of dedicated CargoTube Links through Simulation

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Abstract. Hyperloop is a transportation system which can be used to transport goods fast in high volume at short and middle-distance logistics as a complement to the railway network. A hyperloop system comprise three main elements: tubes, pods, and terminals. The tube is a sealed, low-pressure system. The pod is a coach which is normally pressurized at atmospheric pressure and that runs considerably free of air resistance or friction inside this tube, using magnetic propulsion. The terminal handles pod arrivals and departures.

CargoTube adopts the hyperloop concept and has the potential to ultimately reducing the total energy requirement of transportation and therefore minimizing the Greenhouse Gas (GHG) emissions beyond the capabilities of surface or airborne transport. However, CargoTube relies on more conventional and readily available track technology, like a train or streetcar, to guide and propel the vehicle within the tube. Large diameter steel tubes such as those used in gas or water pipeline infrastructure can be adopted. The CargoTube concept results in a balance between performance, efficiency, and lifetime cost to provide an intermodal cargo transport system for industrial logistics and transportation corridors.

This paper presents how the planning of specific CargoTube routes can be supported by means of an example drawn from the EU-funded research project ePIcenter (epicenterproject.eu/). The example connects a Logistics Service Park (LSP) with an automobile production site. The application of the planning is supported by a discrete event simulation to assess the impact of innovative transportation technologies by simulating selected Key Performance Indicators (KPIs) under different technological assumptions.

Keywords: Hyperloop, CargoTube, Sustainable Transport, Simulation, Discrete Event Simulation.

1 Introduction

Hyperloop is a transportation system that is used to transport goods fast and in high volumes for short and middle-distance logistics complementing the railway network. A hyperloop system comprise three main elements: tubes, pods, and terminals [1]. The tube is a sealed, low-pressure system. The pod is a coach which might be normally pressurized and that runs considerably free of air resistance inside this tube. Magnetic levitation and guidance minimize mechanical friction, propulsion is powered electrically. The terminals handle pod arrivals and departures [2].

CargoTube adopts the hyperloop concept and has the potential to ultimately reducing the total energy requirement of transportation and therefore minimizing the Greenhouse Gas (GHG) emissions beyond the capabilities of surface or airborne transport [3]. However, CargoTube relies on more conventional and readily available track technology, like trains or streetcars, to guide and propel the vehicle within the tube. The use of existing and well-established technology and “stock” components allows CargoTube to significantly reduce the costs associated with development, in addition to facilitating rapidly upscaling transportation networks. The CargoTube concept results in a balance between performance, efficiency, and lifetime cost to provide an intermodal cargo transport system for industrial logistics and transportation corridors [3].

For the planning of the layout and the implementation of such a system many questions need to be answered ranging from the actual routing, layout of terminals, capacity (number of tubes, pods, etc. in relation to planned throughput) to infrastructure setup and operational costs.

The remainder of this paper presents an example that connects a Logistics Service Park (LSP) with an automobile production site. A discrete event simulation model has been built to allow the evaluation of different possible setups and their logistics performance.

2 Method

The discrete event simulation model that has been built using the JaamSim simulation system [4]. The central elements of the model are two tubes going from a Logistics Service Park (LSP) to a manufacturing plant and vice versa. The layout of the simulation model is shown in Fig. 1.

First, a basic data spreadsheet has been defined to collect the necessary input data and to calculate some basic parameters. The spreadsheet is divided into the following sections:

- Objectives: Calculation of the amount of cargo transported each day.
- Constraints: This section mainly collects the size of the boxes and calculates the diameter, total volume, and transport volume per box. The diameter of the box is needed to select the right diameter of the tube.

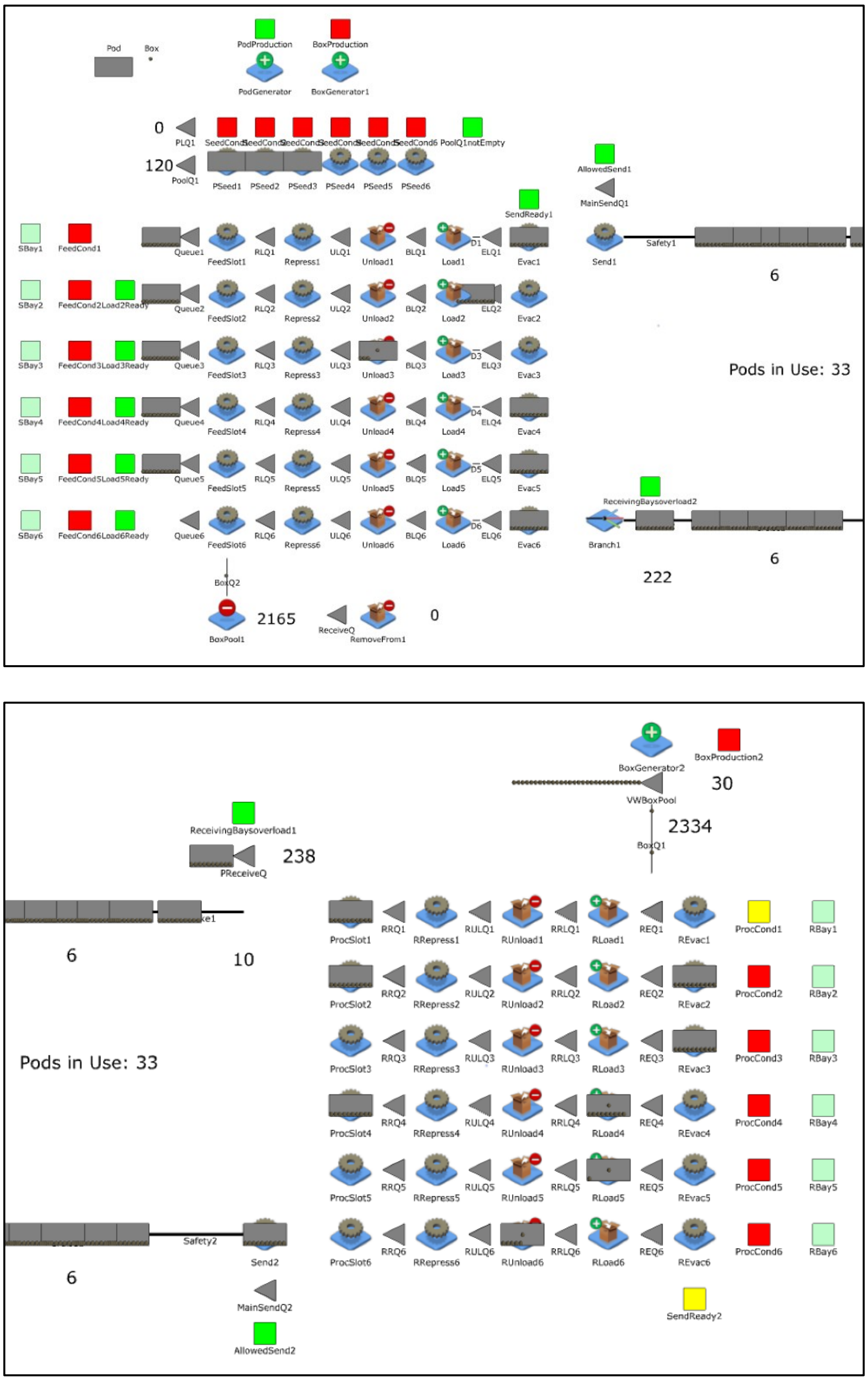

Fig. 1. JaamSim CargoTube simulation model while running. Top is the left side (LSP), bottom is the right side (manufacturing plant).

- Hyperloop Layout: In this section the amount of steel and concrete needed for the tube(s), rails, and pillars are calculated depending on the length, diameter, etc. of the planned system.
- Pumps: This section calculates times and costs for generating and maintaining the vacuum in the tubes based on the specific properties of selected pumps.
- Pod Layout: The pod layout includes the minimal pod diameter, its length, and the blockage ratio.
- Cargo Bay Layout: The cargo bay layout includes the minimal length and the re-evacuation time necessary after any loading or unloading activities under normal pressure.
- Handling: This section collects estimated repressuring and loading/unloading times and calculates the total handling time per pod in a cargo bay.
- Operation: This section calculates some basic operational parameters like travel time, maximum number of pods per day, the minimum number of bays, and the maximum number of pods in the system.

3 Results

The basic data spreadsheet already allows an assessment of the capabilities and performance of the planned CargoTube system, but it is always difficult to assess these numbers in a dynamic environment. Questions concerning the bottlenecks of such a system can only be answered by a discrete event simulation model [5] which takes the basic data as input.

Fig. 1 shows the layout for the discrete event simulation model. The central elements are the tubes going from the LSP to manufacturing plant and vice versa. On each side is a terminal with six bays which can be individually switched on and off (e.g. for simulating maintenance). In each of the bays the single pods are running through a process of waiting (when the bay is in use), repressuring, unloading and/or loading, and evacuation. When the process in a bay is finished the pod is sent into the tube when a specific safety distance from the last pod has been reached. The handling process on the other side is the same with the exception that empty boxes are loaded to be sent back. The model is parameterized in various ways which allows the evaluation of relevant transport logistics indicators like timeliness and throughput under different utilization scenarios.

Analyzing the basic data and the constraints listed above, initial experiments with the simulation model provide the following insights:

- Around 12,600 boxes must be transported each day.
- The CargoTube system is expected to have two tubes of a length of 12 km, one tube for each direction.
- The minimal inner diameter of the tube needs to be 1,65 m resulting in around 14,000 t of steel (for tubes) and 12,000 t of concrete for the floor inside the tube. Further steel and concrete is needed for the rail system and the pillars.
- The total volume within the two tubes is around 45,000 m^3.

- With two pumps the time for tube evacuation down to 10 mbar is around 3 days.
- If a pod used in the tube carries 10 boxes it should have the length of 12.6 m.
- Assuming a repressure time and automated unloading/loading time of one minute each result in a handling time of 4,2 minutes including the evacuation.
- The total travel time for a pod is 5,5 minutes including acceleration and braking.
- The whole system can transport more than 16.000 boxes from the LSP to the plant using six bays on each side and running fully loaded (no waiting times).
- The maximum number of pods in the system is 33 (compared to the calculated number of 36).
- With only five bays in operation on each side, the system is still capable of transporting more than 13,500 boxes per day.
- With only four bays in operation on each side, the system can transport more than 10,500 boxes per day.
- With specific demand curves which simulate the uneven demand of supply during the hours of a day there are a few waiting times which do not last longer than 60 minutes.

4 Conclusions

The design and modelling of a CargoTube system aims to understand how such new concepts in transportation have an impact on freight transport and their contribution to a major reduction of greenhouse gas emissions. Noise, weather exposure, safety, total energy consumption, and the direct GHG emissions inevitably linked with freight transportation will be substantially reduced. Emerging solutions need to be carefully planned, analyzed, and evaluated, to understand what their contribution to a sustainable transport system can be.

The example demonstrates that such a CargoTube can supplement the conventional transport modes. Noise, particulate matter, pollution emissions, and light exposure to the environment, residents, and wildlife are effectively cut off by the low-pressure tube ecosystem. Reduced energy storage requirements and further decreases in environmental impacts result from the use of electric propulsion and continuous recharging in the operation of the enclosed system. The CargoTube design is reliable and flexible while automation reduces costs and personnel requirements. In addition, a high level of automation in a closed tube supports a resilient transport system which can withstand extreme weather conditions. The confined low-pressure environment provides a high level of security for the goods transported. This kind of dedicated, fully automated transport mode supports industry optimization workflows for a reliable just in time supply chain. Significant reduction in road traffic and congestion, especially in urban and densely populates areas, can be achieved.

The only disadvantage is the evacuation time of around three days for the given example, which may take place when maintenance inside the tube is required. For such circumstances it needs to be proved that the pod traffic can start earlier with reduced speed while the tubes are still evacuated.

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