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Improving cost efficiency and environmental impact by mixed freight and passenger's railway transport

Emilio Larrodé[1], Victoria Muerza[2] and Javier Calvo[3]

[1]*University of Zaragoza, Department of Mechanical Engineering, Zaragoza, Spain*
[2]*University of Zaragoza, Aragon Institute of Engineering Research (i3A), Zaragoza, Spain*
[3]*PopRail, s.l., Zaragoza, Spain*

Abstract. This paper shows a model of transport comparison, in which the proposed model improves energetic efficiency and the mobility of goods between rural locations by using passenger's rail transport services. The suitability of the model has been analyzed through the operational simulation, cost estimation and emissions reduction. For this purpose, an existing regional rail transport passenger's service has been used in the simulation between two big cities.

1 Introduction

Light goods such as parcels, may be transported if they are properly integrated into the passenger rail transport service, so that this service can be part of the supply chain and distribution system of goods. The design of this type of service is very different from the model for traditional freight (heavy, bulky, no urgency). The transport of light goods, need comply with the following requirements: (i) the speed and regularity; (ii) the need for real-time information to customers and dealers; (iii) integration of intermodal operations with local freight agencies; and (iv) the use of light equipment for the loading and unloading of goods, making it fully compatible with the passenger transport rail service.

2 Antecedents

In Europe, there are only a few experiences regarding this type of service, like the TGV Postal service in France, considered the most important in terms of freight transport on high-speed lines, now ceased [1], or in Germany, the "CarGo Tram" service at the Volkswagen Crystal Factory in Dresden, sharing infrastructure but not vehicles [2].

3 Proposed model

This paper proposes a model for the transport of light goods that combines passenger's rail transport services, and road transport between two urban centers of neighboring regions, using the same vehicle. The objective is to integrate in a single train the shipments in rural areas with a high supply and demand close to urban areas, thus avoiding the use of several individual delivery vans.

The operative characteristics (OC) of the model are the following:

- OC1: Both nodes (cities) must be connected by existing railways service and road.
- OC2: Urban areas connected by the railway service should have a size and a number of inhabitants large enough to generate a capacity of supply and demand.
- OC3: The model considers the use of medium-distance passengers trains used to connect rural areas and cities, adapting to the available schedules.
- OC4: The railway operator company allows the modification of a coach within the train for the transportation of freight.
- OC5: The model implies the existence of adapted areas in train station for loading and unloading parcels, and an urban delivery operator company at the station in the connected cities.

- OC6: There is a restriction of time to introduce the load into the rail coach while stopping at intermediate train stations.

The movement of light goods comply with the following conditions (C):

- C1: The packages must be handy enough to be transported in a system that allows their groupage.
- C2: Groupage must be done in accordance with the distribution operation in the destination place.
- C3: The grouped system of transport in the train (cage or basket) must have a width of less than 1,000 mm, ensuring its movement through doors and corridors; it must be stable avoiding its movement during the journey.
- C4: Cages or baskets will be previously ready on the platform prior to the arrival of the train, in order to avoid delays in the regular scheduling of the passenger train.
- C5: It is necessary a mechanical device to overcome the entrance step for the loading and unloading of cages in the train.
- C6: In each urban center where the last mile distribution will take place, there must have an operator at the station, responsible for loading, unloading, picking and distribution of parcels by using an electric tricycle or other non-contaminant vehicle type.
- C7: Depending on the quantity of parcels, the distribution process will be partially supported by a part-time delivery employee hired on demand.
- C8: Parcels will be received, classified, grouped and stored at the departure station in a dedicated storage; the operator will be in charge of the packages reception from different suppliers.

Figure 1 shows a comparison between the traditional and the proposed model.

4 Model analysis

This section shows a comparison analysis between both models. The traditional model based in the use of single vans to bring goods from rural areas to the city by road, and the proposed model based on an intermodal use of mixed passengers and freight rail and a last mile approximation by road. In the traditional model, the products from the suppliers are delivered between two big cities using an individual road transportation based on delivery vans, from multiple origins scattered along the geography surrounded the rail track, to the final client in the big city. For the second model proposed, it has been chosen the line Zaragoza - Pamplona[a], with 18 intermediate stations. In the model, we select two final destination cities, Zaragoza and Pamplona, and two intermediate stations (Alagón and Tudela) (Table 1 and Table 2).

Table 1. Schedule line Zaragoza-Pamplona.

	Average distance (km)	Arrival time	Departure time
Zaragoza	-	-	**06.10**
Alagón	25.00	06.43	06.43
Tudela	86.00	07.15	07.15
Pamplona	188.00	**08.32**	-

Table 2. Pamplona-Zaragoza.

	Inhabitants 2016	Arrival time	Departure time
Zaragoza	661,108	**10.05**	-
Alagón	7,045	09.38	09.38
Tudela	35,170	08.59	08.59
Pamplona	195,650	-	**07.43**

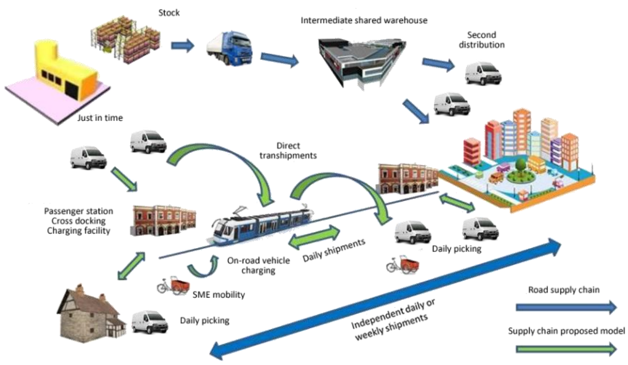

Figure 1. Models comparison.

4.1 Operational variables comparison between pure road and mixed train parcel distribution

4.1.1 Times of service

Traditional model (road)

The traditional model is based on the use of single transport vehicles to deliver the goods from the primary origin (the place where is produced or collected), to the final client (big cities commerce's). Products are loading into the van and a total

[a] http://www.renfe.com/viajeros/index.html

distance *dv* is covered in a time *tv*, being approximately the number of *nv* vans used equal to the number of suppliers depending on the level of sharing of the vehicles (in the analysis we consider that ηv is 30% of the load is shared between vehicles). This sharing percentage is dependent on the closeness of the potential suppliers.

Table 3 shows the distribution distance and the time required for the delivery in every location considering an average speed of the van of 30 km/h. In addition, there will be considered 30 minutes for the customer delivery and parking difficulties will be greater.

Table 3. Traditional model delivery characteristics.

	Zaragoza	Alagón	Tudela	Pamplona
Delivery distance (km)	25	8	12.5	20
Time (h)	1.33	0.76	0.91	1.17

Proposed model (mixed train and last mile delivering)

Table 1 and Table 2 show the journey time for the Zaragoza-Pamplona passenger line train. The distribution times in the delivery tricycle will always vary as a function of the freight quantity and the proximity to destinations (D). On the other hand, it is considered a tricycle average speed(S) of 20 km/h and a maximum of three delivery journeys, a delay time(E) of 10 minutes associated with traffic restrictions, and 30 minutes to deliver the parcel and prepare the tricycle, as expressed in (1).

$$Time(h) = \frac{D}{S} + E \qquad (1)$$

Table 4 shows the characteristics of the delivery for the proposed model by using tricycles. It can be seen in Zaragoza and Pamplona the delivery times are too high, so a new calculation is made considering two journeys, and three journeys in case of Zaragoza.

Table 4. Model proposed delivery characteristics.

	Zaragoza	Alagón	Tudela	Pamplona
Delivery distance (km)	4.5	1.3	1.2	3
Time (h)	2.02	1.06	1.03	1.57
Time (h) 2 routes	1.57	-	-	1.27
Time (h) 3 routes	1.12	-	-	-

Table 5 shows a comparison of the times used in both modes. Journey time has been taken from Google Maps by the simulation of journeys within urban centers.

Table 5. Comparison of times.

Proposed model	Journey time (h)	Distribution time (h)	TOTAL (h)
Zaragoza-Pamplona	2.20	5,68	7,8
Road	Journey time (h)	Distribution time (h)	TOTAL (h)
Zaragoza-Pamplona	2.63	4.17	6.8

4.1.2 Load capacity

The characteristics of the transportation carriage of a Regional Express electric train can be seen in Table 6. On the other hand, for road transportation it is considered the use of a van model Peugeot Partner, very common for delivery labours. This vehicle has a load capacity of 600 kg and a capacity of 3m^3. It is considered the driver has a standard weight of 75 kg.

Table 6. Carriage capacity Regional Express electric train.

Surface for the transportation of goods (mm)	4,100x2,700
Seats to be removed	12
Aisle width (mm)	1,110
Space between cages	50mm

For the calculation of the train load capacity it is considered the maximum number (N) of cages to be transported, the standard cage volume (800x720x1,800 mm) and the freight volume according to expressions (2) and (3).

$$N\ Cages = \left(\frac{Lenght\ transportation\ area}{Cage\ width}\right) * 2 = \left(\frac{4{,}100}{770}\right) * 2 = 10.64 \approx 10 \qquad (2)$$

$$Freight\ volume = N\ Cages * Cage\ Volume = 10\ m^3 \qquad (3)$$

The maximum load of a passenger's carriage is calculated through the sum of the average seat weight (30 kg), plus a standard passenger weight (75 kg) and a standard passenger's luggage (15 kg) considering the twelve seats removed (see expression (4)).

$$Weight = 12\cdot(30 + 75 + 15) = 1{,}440\ kg \quad (4)$$

The number of vans to transport the same load is calculated as:

$$N\ vans\ per\ volume = \frac{10}{3} = 3.33 \approx 4 \quad (5)$$

$$N\ vans\ per\ load\ capacity = \frac{1{,}440}{525} = 2.74 \approx 3 \quad (6)$$

4.2 Cost analysis

4.2.1 Proposed model costs

A distribution between initial investment, fixed and variable cost has been estimated. For the Initial investment we are considering the acquisition of delivery electric tricycles, cages, mobile loading and unloading platforms and the reform of the train. For the fixed cost, we assume the cost of operators, equivalent train tickets, transport activity licenses, rental of premises, insurances…The variable cost depends on the freight (extra operators, extra tricycles).

4.2.2 Traditional model costs

Costs have been calculated by means of the cost simulation software ACOTRAM, developed by the Dirección General de Transporte Terrestre[b].

4.3 Analysis of emissions and consumptions

The analysis of emissions and consumptions considers the consumed energy and the emissions of Greenhouse Gases and Particulate Matter (PM10). The analysis has been made by using the simulator EcoTransIT World.

The energy consumption is analyzed according to the freight volume, which is a more restrictive factor than the load capacity. The energy consumption in the train will remain constant, as it does not substantially influence the freight considered in this research with regard to the total train weight. Results are shown in Table 7 and Figure 2.

Table 7. Consumption, GHGs and PM10 according to transport mode.

	Consumption (kwh)	GHGs (ton)	PM10 (kg)
Van	1,006	0.26	0.08
Train	121	0.02	0.008

[b] Available at www.fomento.gob.es

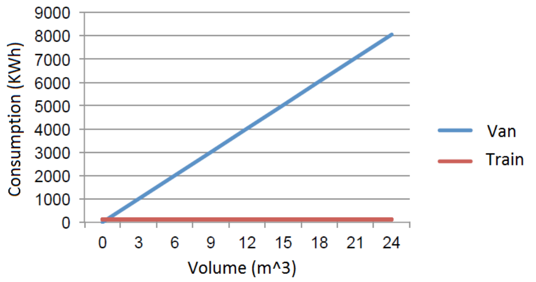

Figure 2. Energy consumption according to the freight volume.

5 Discussion and conclusions

Nowadays, manufacturers of rural products send its products to the city three or four times a week due to accessibility issues and availability of means of transport. With this intermodal railway-logistic urban system, it is possible to have an almost daily accessibility at a not exceeding cost, and thus offering a better service to the customer.

Road transport is more competitive than rail transport, as expected. One of the main advantages of road transport is its high flexibility, which is essential for customers who require short transit times.

However, the advantages of the model proposed imply:

- Reduction of motorized delivery vehicles in the city and therefore emissions.
- Improved accessibility from rural areas to freight urban distribution service.
- Improved energy efficiency of the global distribution operation.

References

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