A Basic Developmental Scenario for the Maglev Highway

— Maglev Highway as the Future of Transport —

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Abstract

A Maglev system, in which cars sit on magnetically levitated pallets, could potentially produce substantial benefits compared to conventional car travel, particularly on long distance routes. This paper describes basic developmental scenarios applied to the future of high-speed ground transportation.

1 Introduction

Maglev systems were initially designed for use with trains:[1][2], where they were seen to provide substantial benefits by removing many of the problems associated with steel wheels on steel rails. In particular, Maglev systems are not limited to 350-400km/h, the practical maximum speed of a steel wheel on rail. (The maximum speed of wheel-rail was 515.3km/h, recorded in France, but only with dry rails and very good conditions.)

Furthermore, the maintenance costs of conventional rail systems are high because of wear between the wheel and rail, while reduced maintenance can lead to a lack of reliability and increased accident risk. Maglev systems have progressed substantially in the several decades since their first invention and practical systems are now operation. The novel concept of the Maglev Highway (i.e. Maglev in highway mode) using pallets, on which the vehicles sit, was proposed at Maglev 2000 in Rio de Janeiro, Brazil [4][5][6]. This paper takes that concept forward by describing the system scenarios of a Maglev pallet system, particularly with reference to the highway mode, which would be used to transport private cars and small goods vehicles.

2 Basic Characteristic of Maglev Pallet Transport

The system is based on the concept of a pallet onto which each vehicle is driven and which is then automatically controlled on a segregated roadway. A pallet based Maglev system has many advantages [4][5][6]:

(1) High-speed operation and high capacity, making it particularly ideal for long distance routes where a car user benefits from the comfort/facilities of their own vehicle without the driving responsibility.

(2) Increased safety, an important issue when over 40,000 people are killed each year both on European and American roads, with 10,000 killed in Japan. Almost all accidents involve driver error and a system where a pallet moves automatically on a Maglev guideway system will remove driver error.

(3) Ownership of the system would be such that clear responsibility for service levels and maintenance would not reside with a single authority.

3 Issues of Development

The future vision of any new transportation system may be attractive, but the process of moving from the present to the future is often unclear. Previous new transportation concepts have often tended to ignore consideration of compatibility to the car/highway system, thereby removing the practical possibility of their evolution. Equally, concentration on the present can lead to a focus on only short-term incremental change rather than more innovative approaches that may be necessary to meet future environmental, energy, safety, capacity, and reliability issues.

Any new system, such as that described in this paper, must take into account motor vehicle ownership and usage. Motor vehicles and roads dominate ground transportation and the convenience of the car, particularly for personal and door-to-door transport, will ensure this domination will continue for some time.

Maglev is an alternative to the wheel. In the past, Maglev trains were considered as competition for the high-speed airplane [1]. However, in train applications, a high speed switching system is not practical [4][5[6]. In a car-highway situation, the main focus of levitation during high-speed switching is critical. The differences of the targets between train and highway modes are shown in Figure 3-1.

Figure 3-1 The New Development Targets of the Highway Mode Maglev

4 Planning

4.1 Introduction

For any new development there are usually three phases: planning, construction and in-service. In established areas of application, e.g. conventional train and highway, these phases are sequential. In the planning phase, an engineer has available known data on construction and operating costs and performance figures for all elements of the transportation system.

The situation is different where radical innovation is employed, where the engineer has to consider the downstream phases, such as building, operation and maintenance performances, from the initial planning phase.

In such circumstances, there will be initial uncertainty concerning construction, operation and maintenance, and feedback will be required between upstream and downstream phases using the limited data currently available. For example, it would be very difficult to evaluate a system balancing supply and demand between the new system and the interface with the conventional road networks.

4.2 Past Experiences

Historically, system engineering developed the Phased Planning System used in the Apollo lunar project. The Mission of the Apollo Project was largely the result of a clearly stated national political goal, which was achieved because of the national prestige involved. In 1961, President Kennedy declared that America would send a man to the moon by 1970. The Apollo mission had a simple and very strong concept, which enabled NASA's huge budget to be accepted, even when the downstream details were unknown. Any such large impact innovative scheme would need a National Goal to open the gates of downstream phases.

4.3 The New Phased Planning System

A new Maglev Highway system would be considered to be of a similar scale of activity to the Apollo program. In spite of its huge potential scale, it seems to be difficult to set the strong national prestige like Apollo program, due to more complicated milestones. Therefore we will need the new phased planning systems. The key characteristics of the new phased planning systems are a fundamentally feedback loop procedure at each stages so as to get the public acceptance step by step. Of course, it would be better to get the same sort of commitment and processes to make it happen and achieve these potentially high national benefits. The form of the proposed process is described in the following section.

5 Basic Steps for development

5.1 Overviews

Considering the innovational development, the motivation process is important.

The first motivation of the innovational development would be the personal dream.

Once a people have a dream for the future transportation in her/his mind, she/he will be able to go ahead. First motivation will be born from the mental issues, namely it would be dream [3].

Therefore, the mental issues are important for the trigger of the first step of the innovational development. The images define as the mental picture. If there are no images (picture in the mind) for the new transportation systems, people can not imagine the pictures of the new transportation systems in their mind and can not understand the systems, and how to operate them, and support to development.

The Common images of the people will produce the common supports of the people [9].

The first step in the development of a Maglev Highway system will be to develop the core concepts of safe, high speed movements of people in their own vehicles without the need to drive. But the idea of riding the pallet is not yet established. Therefore, it is important that, once the core concept(image) is settled, public acceptance of the idea is generated quickly.

5.2. Importance of the Beginning

The Core Concept (Image; mental picture) is most important for Maglev Highway development, as shown in Figure 5-1. The core concept must be successful to ensure a final product, which addresses needs, and these initial activities will dominate the downstream phases (Figure 5-2)

Figure 5.1 An Image of the Maglev Highways

Figure 5-2 Importances of the Images

6 Difficulties of the Maglev in Highway Mode

6.1 Maglev in highway mode

The main reason why Maglev technology emerged was for the super high-speed train. As the main target of the Maglev train was speed, this made it simpler than the highway mode, where transport characteristics are more complex. For example: speed, traffic capacity, energy efficiency, headway, accessibility, safety level, impact on the environment, and acceptability of ride level should be assessed.

6.2 Difficulties about Maglev Highways

Once the construction of a highway mode Maglev system begins, the design level has ended. The distribution of Maglev construction will be spread throughout highways, having a crucial impact on ground transportation. The Maglev Highway can work efficiently as a network system; the interchange between lines is a most important aspect and must be fundamental to design.
The difficulties of the Maglev Highway can be summarized as shown in Table 6-1.

Table 6-1 Difficulties of the Maglev Highway

Items	Train Mode Maglev	Highway Mode Maglev
Maglev Core Concept (Idea, Image)	Already established (People can imagine Maglev Train)	Not established (People can not imagine Maglev Highway well)
Public Acceptance	Some Project Already established	Not established
Target to Develop	Simple	Complicated
Technologies	Many technologies developed	Few, but may be applied to Maglev Highway
Target of Vehicle	Public Transport Vehicle Freight Container	Passenger Car, Various Trucks, Freight Container,(even Transit vehicle, Train Vehicle)
Integration with Existing Highways	Not important	Should be integrated with the existing highways
Networkability	Not important	Crucially important
Range of Design	Many designs possible.	Coordination of a standard is critical
Potential Market	Medium	Very large

7 Analyses of Scenarios for Development

7.1 Potential Market of Maglev Highways

In the USA alone, several tens of thousands of kilometers of highways could be operating magnetically levitated pallets. Once shown to be a success, the world market would be many times that size and add to the increasingly important sustainability objectives.

7.2 Scenario for Development

The developmental scenario relates to the motor vehicle system as shown in Figure 7-1.

Figure 7-1 Basic Flowcharts for Exploring Scenarios

This basic flow was investigated. Road has the greatest share of passenger transport in major countries as shown in Figure 7-2[10].

Figure 7-2 Passenger Transport by Mode of UK

Whilst Japan has one of the most developed railways, automobiles accounted for 67% of passenger transportation on the passenger km based survey in 1999. (Railway's share is 27%).
The main targets of a pallet system are as follows:
1) Cars, 2) Light Goods Vehicles, 3) Other Good Vehicles, 4) Others.
In the UK, the average vehicle proportions of motorway traffic for 1994 are given in Figure7-3.

Figure 7-3 Average Category Proportions of Motorways in UK

There are three scenarios for the developmental of the Maglev pallet connected to highway use (Table 7-1).

Table 7-1 Development Paths of Maglev Pallet Transport

Scenario No.	**Target of Vehicles**
Specialized Path (**SP-1**) for passenger	Passenger Cars
Specialized Path (**SP-2**) for freight	Freight (Truck, Container, etc)
Integrated Path (**IP**) for passenger and freight together	Passenger Cars and existing Freight (Other vehicles and Containers)

The merits and demerits of each scenario are given Table 7-2.

Table 7-2 Scenario Merits and Demerits

Scenarios	Merits	Demerits
SP-1	More concentration on huge passenger cars would give the greatest cost reduction. This would solve the congestion of existing highways, as most congestion is caused by passenger cars.	It would not be able to accommodate the heavy vehicle issues, for example, the maintenance caused by heavy trucks.
SP-2	It would accommodate the environmental pollution caused by heavy trucks.	Very difficult to open this market because the potential usage is not so great, compared to passenger cars.
IP	For every vehicle: cars, trucks, trailers, and containers.	More complicated design, higher cost.

7.3 Comparison with Passenger Car and the Others

From the cost reduction view of guideway construction, it is best to concentrate on the passenger car mode of Maglev Highways, as trucks and trailers are too heavy[11].
Also, designing for all vehicles is excessive (Figure 7-4).

Figure 7-4 Comparison Weight between Car and the Other Vehicles

The next step investigated the moving performance difference between passenger cars and the freight mode. The results were as follows (Figure 7-5).

Figure 7-5 Comparison Moving Performances between Car and Other Vehicles

PS: horsepower, T: weight (ton)

8 New Transportation Mode: Hyper-modal

There are now two main types of ground transportation mode: mass transportation mode, and individual transportation mode.
When cars ride on pallets, the mode is mainly individual mode, but its essential features can be applied to mass transportation mode for the train mode. This Maglev pallet transport can be used for not only highway mode but also train mode[7][8]. Intermodal is defined as the linkage mode

between the different modes of transportation systems, but Maglev pallet transport can be used as a new mode that integrates cars, transits, and even trains. We can use the various different modes in only one lane. We call this new transport mode “hypermodal”.

The following figure shows the difference between intermodal (multimodal or integrated modal) and hypermodal.

Figure 8 Comparisons between Intermodal and Hypermodal

9 Running Resistances

We investigated how the running resistance of cars is changed by the Maglev pallet.

In general, there are three main components of vehicle running resistance—aerodynamic resistance, rolling resistance and gravity resistance—which are related as follows[11]:

$$R = \mu W + \frac{1}{100} Wi + \lambda S V^2 (kg) \qquad \dots \quad (1)$$

where,

W: vehicle weight,

S: cross-sectional area of the vehicle,

μ : coefficient of rolling resistance,

λ : coefficient of aerodynamic resistance of the vehicle

Average values for the vehicles can be assumed as follows.

Vehicle Type	μ	λ	S (m^2)	W (kg)
Passenger car	0.015	0.0025	2.0	1700
Truck	0.01	0.0035	6.2	14000
Trailer	0.01	0.0040	7.0	32000

In the case of a flat line, the second term of the equation can be neglected, hence:

$$R = \mu W + \lambda S V^2 (kg) \qquad \dots \quad (2)$$

In the case of the Maglev pallet,

$$R = (\lambda S + \lambda_P P s) V^2 + M (kg) \qquad \dots \quad (3)$$

where,

Ps: cross-sectional area of the pallet

M: magnetic running resistance, depending on the weight: 1/800 - 1/500 W

Therefore, the strength can be neglected.

λ_p: Coefficient of aerodynamic resistance of the pallet

	Width	Thickness	λ_p	S (m^2)
Maglev case 1	200 cm	20 cm	0.004	0.4
Maglev case 2	200 cm	10 cm	0.004	0.2

At the speed of 200 km/h, we calculate the running resistance as follows.

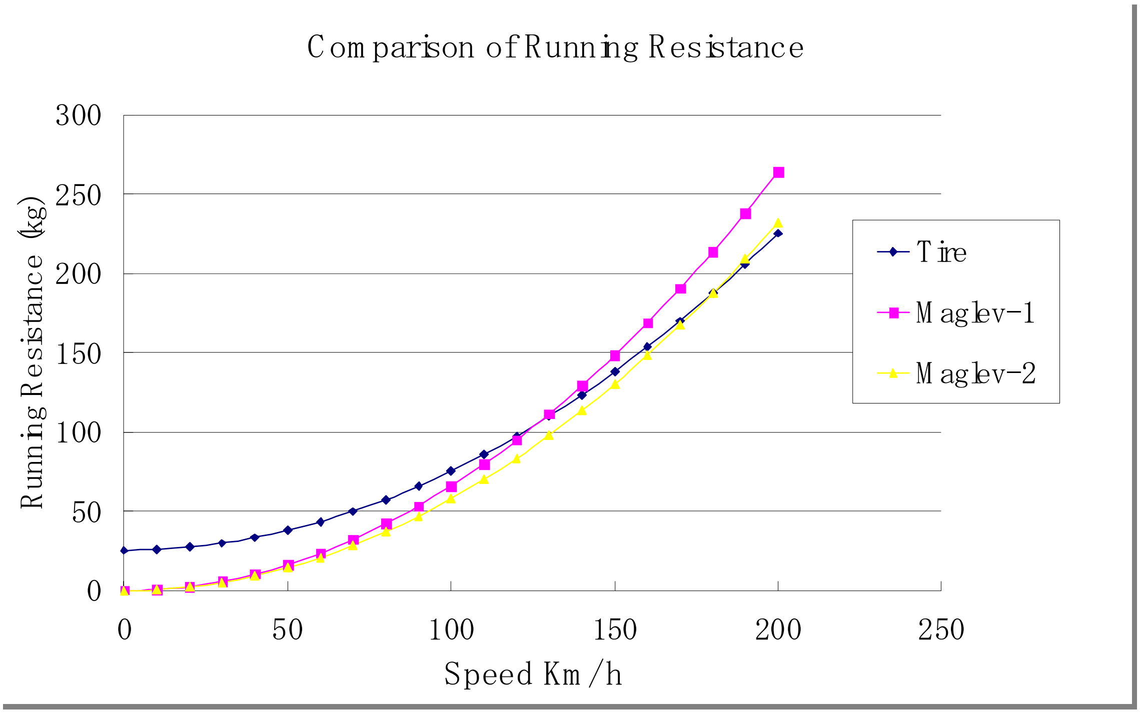

Figure 9 Comparisons between Tire and Maglev

This Figure shows that Pallet needs thinness to reduce aerodynamic resistance.

10 Conclusions

A fully integrated Maglev Highway solution incorporating heavy freight and goods unit movements is too excessive and complex for initial development. Also, the drive for reducing journey time is mainly for passengers and lighter goods.

This paper makes clear the importance of developing a clear core concept that can be promoted to develop usage for the highway mode Maglev. This study is not detailed, but has set out key concepts for a future transportation system development.

For the basic scenario of developing a Maglev Highway system, the target specifications for the fundamental development of the highway Maglev are explored and recommended as follows.

1 Generally, in most countries, it would be better to specialize in the passenger car mode Maglev as a first stage of development.
2 This very compact pallet will be useful for new high-speed freight operations.
3 This pallet will also be useful as a base platform for high-speed smart transit and even for trains.
4 In addition to these strategic scenarios, which are compatible with existing passenger cars, Maglev technology will spread to many modes, and create new automated transport.
5 Pallet size should be compacted from a reduction of the aerodynamic resistance point of view.
6 Pallet size and basic guideway size are critical and will require international cooperation to take account of the characteristics of road networks across the world.

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