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FUTURE HIGHWAYS

Future Vehicles

Feasibility Study On The Application Of Modular Combination Vehicles In China Road Transport

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Ph.D

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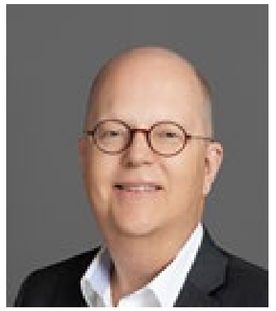

Tommy Xu

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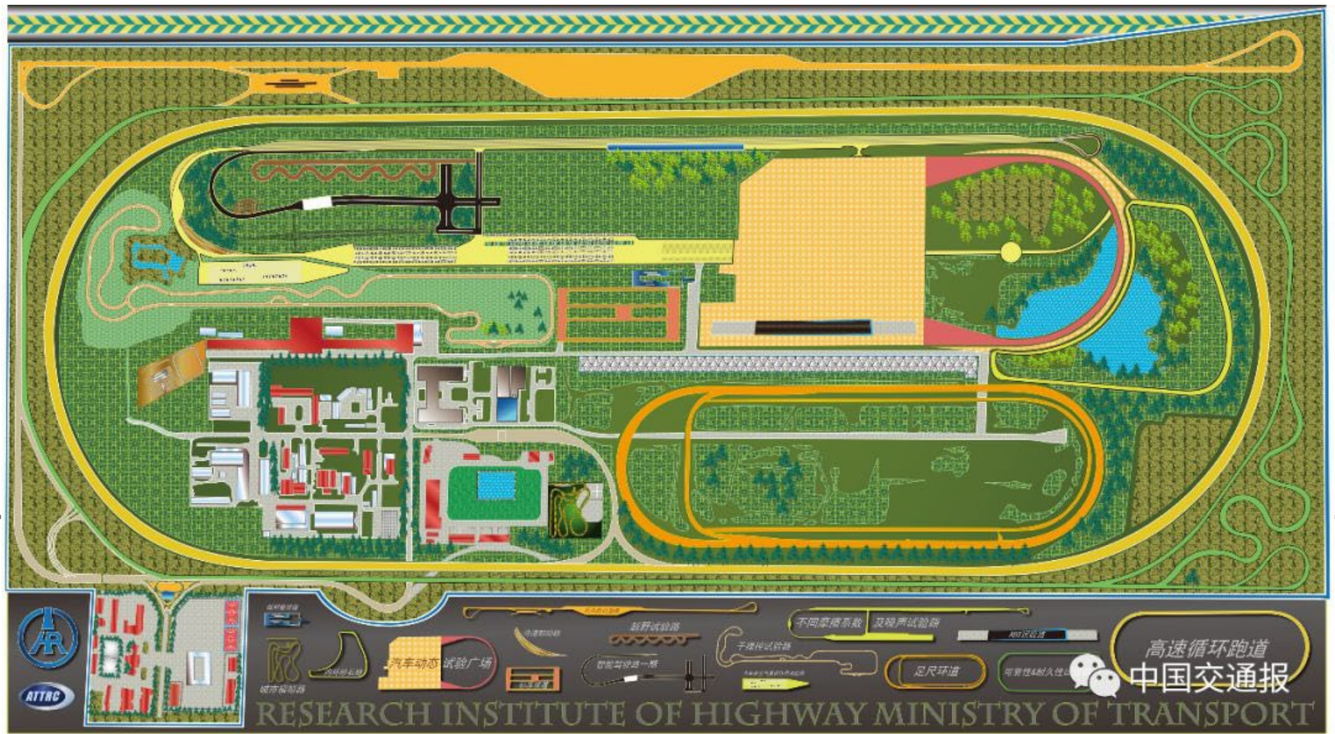
Hamilton, New Zealand

Who is RIOH?

- Research Institute of highway (**RIOH**), Ministry of Transport：since 1956， more than 3000 employees
- Technical support unit for road transportation policies, regulations and standards
- 3 National Inspection and Testing Center：Road and Bridge，Transportation Safety Facilities，Vehicles
- Secretariat of 8 Standardization Technical Committees
- Testing ground：2.4 square kilometers



1.1. Background

- Commercial Vehicle Population

Year	CV Population (million)	Goods Vehicle (million)	Tractor (million)	Trailer (million)	Tractor+Trailer /CV (%)
2018	14.35	13.55	2.37	2.48	35.88
2020	11.71	11.10	3.10	3.34	58.14
2022	12.22	11.66	3.54	3.61	61.33

- Transportation Volume

Year	All freight transport (billion tons)	Road freight transport (billion tons)	Road/ All (%)	All freight turnover (trillion t-km)	Road freight turnover (trillion t-km)	Road/ All (%)
2018	50.62	39.56	78.15	19,938.50	7,124.92	35.73
2020	46.44	34.26	73.78	19,676.09	6,017.18	30.58
2022	50.66	37.11	73.27	22,616.09	6,895.80	30.49

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1.1. Background

- GB 1589-2016 Limits of dimensions, axle load and masses for motor vehicles, trailers and combination vehicles

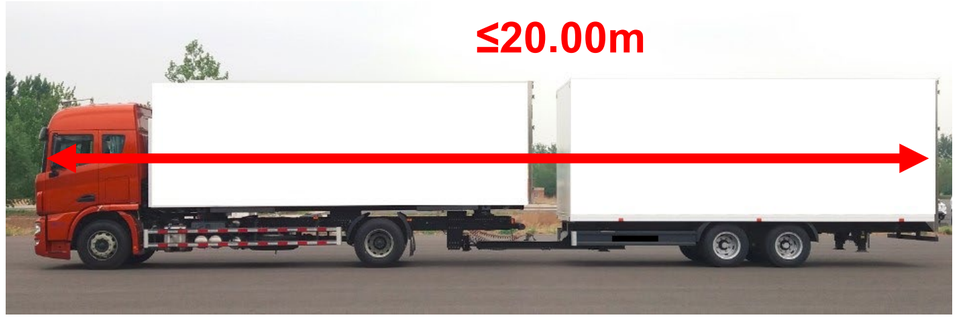
The masses and dimensions standard for road vehicles GB1589 has been continuously updated from the
-Original version of 1979, updated in 1989, 2004 and 2016.

-No significant changes

-Rigid+center-axle combination is 20 m, car carrier rigid with a center-axle trailer 22 m.

-The Road Traffic Safety Law don’t allow for dual-trailer road trains on designated Chinese roads

-Due to road safety related laws and regulations, further expansion is still restricted.



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1.2. Challenges

- The real-life situation market actors use loopholes of oversized container boxes on compliant standard semi-trailers rigids of 130-150 m3 to exceed the present volume standard of container box semi-trailer 95 m3
- Use goosenecks for transport of high volume cargo
- Leads to large transport safety problem and unlevel playing field competition.

Oversized container box on a compliant semitrailer chassis

Gooseneck flat low bed semitrailer

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1.3. Development of Environmental and Emissions Requirements

- Transport account for 11% of the total emissions, road transports accounts for 73% of all transport modes.
- The Chinese government has announced that it will achieve carbon peak by 2030 and carbon neutrality by 2060.
- China's Ministry of Transport has formulated a detailed implementation plan.
- RIOH signed the Cooperation Agreement on the Joint Implementation of the Safe, Low-Carbon and Efficient Transport Pilot Project with Jinzhong City, Shanxi province, Ganzhou City, Jiangxi province, and Hami City in the Xinjiang province, to carry out modular multi-trailer road trains.

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2. Experience of Using Modular Trailer System

2.1. USA

In 1991, the United States Congress passed the Intermodal Surface Transportation Efficiency Act (ISTEA, commonly known as the Iced Tea Act). In order to coordinate and handle the relationship between larger trucks and highway safety. The Congress passed the Federal Size Regulation for Commercial Vehicles, Longer Combination Vehicles (LCV) which allows extra-long road trains on dedicated state highways or toll roads.

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2.2. EU

When Sweden joined the European Union in 1995, it had to adopt the same vehicle standards as other EU member countries, the European Council Directive 85/3 EEC (Masses and Dimensions). The maximum total length of a road train was at first reduced from 24 meters to 18 meters, and the maximum total mass was reduced from 60 ton to 40 ton. In order to efficiently meet with forestry transportation needs in Sweden and Finland, the European Union in 1996 launched the European Modular System (EMS, or EuroCombi), which is a modular combination system of trailers and towing vehicle, based on two standardized loading platform units (7.82m or 13.60m) as defined by the EU Directive 96/53/EC. Member countries are, under this directive allowed, to combine and use road train combinations of different lengths and gross train weights.

Year	Country	Vehicle Spec
2013	Netherland	60t/25.25m
	Finland	76t/25.25m
2014	Denmark	60t/25.25m（Long-term testing）
	Norway	60t/25.25m
2015	Sweden	64t/25.25m
2016	Spain	60t/25.25m（Special permission）
2017	Germany	40t/44t/25.25m
2018	Sweden	74t/25.25m
2019	Finland	76t/35.5m

Summary statistics of EMS regulations changes

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3. China Ongoing Pilot Case Studies

2019-2021

Length: ≤26.00m， Weight: ≤49.00t

2019-2021

Length: ≤26.00m， Weight: ≤49.00t

2021-2021

Length: ≤28.00m， Weight: ≤40.00t

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3. China Ongoing Pilot Case Studies

2019-2021
2022-now

Length: ≤26.00m， Weight: ≤73.00t

2022-2023

Length: ≤26.00m， Weight: ≤67.00t

2023-now

Length: ≤22.00m， Weight: ≤91.00t

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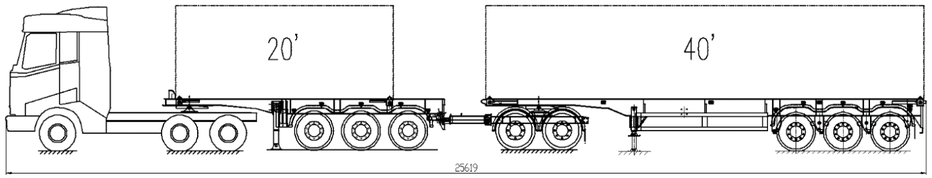
3. China Ongoing Pilot Case Studies

2023-now

Length: ≤26.00m， Weight: ≤91.00t

2023-now



Length: ≤26.00m， Weight: ≤91.00t

The above vehicles were all tested on the testing ground, which does not mean that China will eventually use the above limit values.

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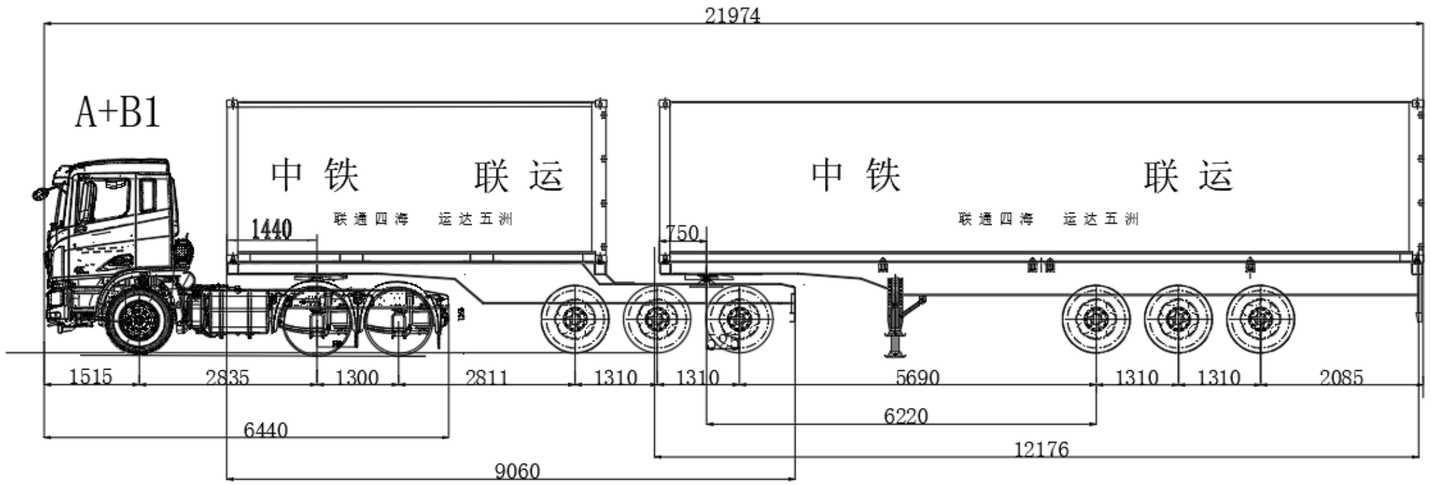
3. China Ongoing Pilot Case Studies

3.1. China Railway Intermodal Logistics

aims at greatly improving the efficiency of the transfer of containers between railway and road in the railway container depots.



By adding more axles than the GB1589 allowed and keeping with the axle and bogey weight limits, the total gross weight of the road train can adds up to 74 tons, with a payload of max 56 tons. This road train can transport 3X20 foot containers or 1X40 foot + 1X20 foot containers. Under the current legislation only 2X20” or 1x40” can be transferred from train to truck at the depot. A 50% efficiency improvement is thus possible using a modular multi-trailer road train.

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3.1. China Railway Intermodal Logistics

Real transport cost operations based on a typical Chinese transport company

Annual Mileage 150k km		CRMT		Tractor/ Semi-trailer	
Fixed Cost	Labour	320k RMB(China currency)/y	2.13 RMB/km	320k RMB/y	2.13 RMB/km
	Depreciation	114k RMB/y	0.76 RMB/km	85.7k RMB/y	0.57 RMB/km
	Interests	44.8k RMB/y	0.30 RMB/km	33.6k RMB/y	0.22 RMB/km
	Total	478.8k RMB/y	3.19 RMB/km	439.3 RMB/y	2.93 RMB/km
Variable Cost	Fuel	2.7 RMB/km		2.4 RMB/km	
	Toll	4.1 RMB/km		2.6 RMB/km	
	Total	6.8 RMB/km		5.0 RMB/km	
Total Cost		9.99 RMB/km		7.93 RMB/km	
Unit Freight cost (expressway)		**0.178 RMB/km.t**		0.227 RMB/km.t	
Unit Freight cost (non-expressway)		**0.105 RMB/km.t**		0.152 RMB/km.t	

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3.2. China International Marine Containers Group CIMC

CIMC Vehicle (Group) Co., Ltd. (CIMC) is a global leader in the high-end manufacturing of semitrailers and special vehicles. Fully compliant vehicles that can increase the loading volume capacity and meet the road transportation standards need to be introduced.

CIMC semitrailer/center-axel trailer truck train

The total loading volume reach about 150 cubic meters, 50% higher than the existing semi-trailer and rigid+center-axle trailer combinations.

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4. Traffic Safety Tests of CAERI and CIMC

China Automotive Engineering Research Institute (CAERI) and (RIOH) conducted comprehensive road train safety and validation tests for the two pilot projects

4.1. CRMT test by CAERI

During tests of the CRMT it was verified that it meets with Chinese standards with regards to breaking, swing amplitude, roll over and handling stability. The engine power also met with Chinese calculation standards.

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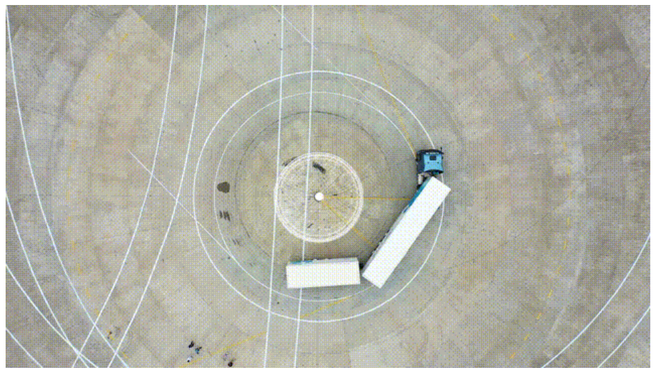
4.2. CIMC test by RIOH

RIOH, together with Xiangyang Da'an Automobile Testing Center and CIMC, conducted a performance test to verify the compliance of the dual-trailer road train and to verify the feasibility of the dual-trailer road train based on the PBS method. In March 2023, all performance tests and 2500 km of reliability tests were completed. A full-load test of the entire vehicle was carried out for dual-trailer road trains with a maximum allowable total mass of 60t and for semi-trailer train with a maximum allowable total mass of 49t.

roll stability test



Turning clearance circle

Power Performance

PASSING CAPACITY(m)		
Inner circle radius	Outer circle radius	Required road width
5.30	14.14	8.84

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4.2. CIMC test by RIOH

Handling Stability

Fuel consumption tests of semitrailer combinations and dual-trailers road trains where conducted under constant speed conditions of 40km/h, 50km/h, 60km/h, 70km/h, and 80km/h, and driven for 500 km. The test shows that the fuel consumption of a standard semitrailer combination was per 30.73 liters/100km and the fuel consumption of a dual-trailes road train was 35.92 liters/100 km.

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4.2. CIMC test by RIOH Conclusion

- The pass-ability of a road train is not as good as that of a semitrailer combination. Fitting a rear-end steering axle on the trailer is one possible solution to improve the pass-ability of the road train.
- The outer diameter of the GB1589-2016 might be revised
- Compared with semitrailer combinations, the total mass of a CIMC dual-trailer road train has been increased by 22.5%(49.00t → 60.00t), and the total freight volume has been increased by 64.8%.
- When selecting a reasonable engine, there is no significant difference in the maximum speed between a dual-trailer road train and a semitrailer combination at full load.
- Under constant speed conditions, the fuel consumption per 100 kilometers of a dual-trailer road train is 16.89% higher than that of a semitrailer combination.
- Considering the added value of mass and volume, the advantages of a dual-trailer road train are obvious.

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5. Comparative analysis of domestic and foreign highways

RIOH evaluate the operating conditions and feasibility of dual-trailer road trains with regard to China's existing road infrastructure.

5.1. Expressway lane width

The width of the highway lane directly decides the safe use of dual-trailer road trains for normal operation and turning. The China highway route design standard (JTG D20-2017) stipulates a highway lane width of 3.75m,which is the same as that of European highways.

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5.2. Turning radius of highway lane

The turning radius of the highway lane directly affects the turning dual-trailer road trains. Because a highway permits high speeds, the road turning radius has to be larger compared with ordinary highways.

Turning radius limits for European highways

Design Speed（km/h）		120	100	80
Minimum radius of circular curve（m）	General value	998	638	360
	Limit Value	665	425	240

Turning radius limits for highways in China

Design Speed（km/h）		120	100	80
Minimum radius of circular curve（m）	General value	1000	700	400
	Limit Value	650	400	250

Note: The maximum superelevation value is 8%.

The minimum turning radius of Chinese highways is generally greater than that of European highways, with a deviation of about 4% at high speeds and medium to low speeds.

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5.3 Highway Ramp

A highway ramp is a road on the right side of the entrance (or exit) of a highway, usually an acceleration lane for entering the highway or a deceleration lane for exiting the highway.

Design speed of highways（km/h）		80	90	100	110	120
Ramp design speed（km/h）	Recommended value	70	75	85	90	95
	Lowest value	40	45	50	50	55
Ramp radius（m）	Recommended value	165	195	245	310	310
	Lowest value	45	65	70	70	90

General Principles and Technical Standards for Expressway Ramp Design

it is confirmed that the road requirements in China are basically the same as those in Europe, confirming that dual-trailer road trains can be safely used on Chinese highways.

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6. Revision of Relevant Standards

- JT/T 1100-2016 Trailer converter dolly
- GB/T 32861-2016 Road Vehicle – Location of electrical and pneumatic connections between towing vehicle and trailers（ ISO 4009:2000，MOD，ISO/AWI 4009，Lead by China）
- GB/T 39015.2-2020 Road vehicles--Interchangeability of mechanical couplings between tractors and semi-trailers--Part 2: Low-coupling tractors and high-volume semi-trailers（ISO 1726-2:2007，MOD）
- GB/T 41651-2022 Road vehicles—Mechanical coupling between towing vehicles with coupling mounted forward and below and centre-axle trailers—Interchangeability（ISO 11407:2004，MOD）
- GB/T 41656-2022 Road vehicles—Mechanical coupling between towing vehicles with rear-mounted coupling and drawbar trailers—Interchangeability（ISO 11406:2001，MOD）

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6. Revision of Relevant Standards

- GB/T XXXX— 2024 Road vehicles — Coupling equipment between vehicles in multiple vehicle combinations — Strength requirements（ Approved plan number ：20214703-T-339）（ISO 18868:2003，MOD， Approval ）
- GB/T XXXX— 2024 Road vehicles — Drawbar couplings and eyes for rigid drawbars — Part1: Strength tests for general cargo centre-axle trailers（ Approved plan number ：20214901-T-339）（ISO 12357-1:2007，MOD ， Approval ）
- GB/T XXXX— 2024 Road vehicles — Drawbar couplings and eyes for rigid drawbars — Part2: Strength tests for special applications（ Approved plan number ：20214960-T-339）（ISO 12357-2:2007，MOD ， Approval ）

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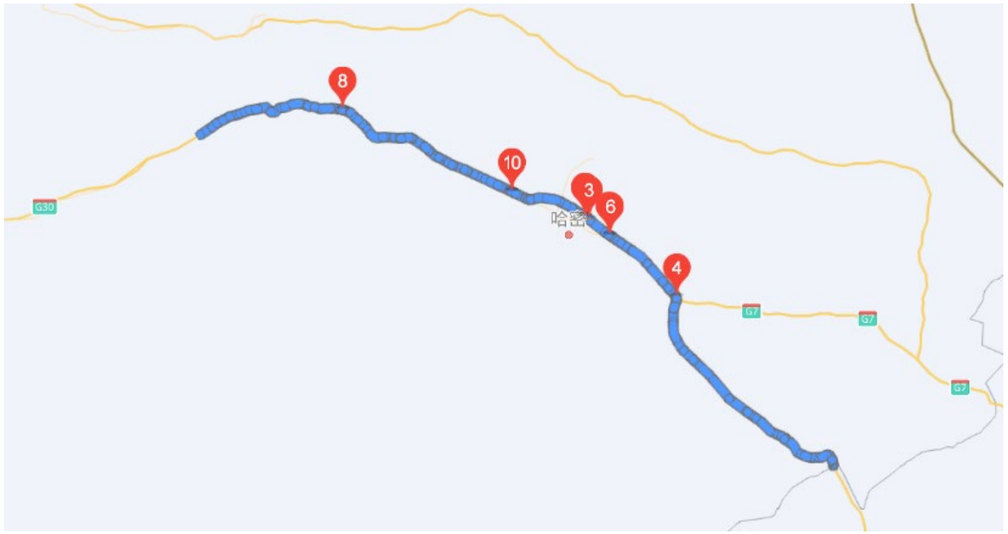
7. Pilot situation

Ganzhou
120 km



Hami
400 km

Wulanchabu-Erlianhaote
340 km

The pilot demonstration work will be conducted in 2024.

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8. Conclusions

- In summary, equipment manufacturers and logistics companies have made a variety of attempts under the backdrop of current restrictive standards and laws, to design high capacity road trains.
- RIOH has carried out practical pilot projects together with transportation enterprises in several geographies. The prospects of a road transport modular system and its transportation applications are feasible in China.
- With China’s stated dual carbon goals, the road transport modular system is an excellent way to simultaneously achieve carbon reduction and efficiency improvements for enterprises, society and government. It can furthermore help reduce the number of fatal road accidents. What is lacking are amendments of the existing GB1589 standard and of the Road Traffic Safety Law to allow for dual-trailer road trains on designated Chinese roads. We still need to do further work to gradually promote the application.

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