DRAGO SEVER, D.Sc.
Univerza v Mariboru
Fakulteta za gradbeništvo
Oddelek za promet
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REAL CAPACITY OF ROPEWAY TRANSPORTATION SUBSYSTEM

ABSTRACT

The ropeway transportation subsystem plays a major role in mountain resort systems. It is characterised by an exceptional interweavement of interactions of single system elements. In order to provide sustainable development of the entire mountain resort systems, the real capacity of the ropeway transportation system was set. Real capacity of the ropeway transportation system is one of the indicators of the development harmonisation level of single system elements. The research into this field was done at Road and Traffic Centre of Faculty of Civil Engineering, University of Maribor.

The article deals with basic points, with method and the results of research. It also represents some experiences of know-how transfer into the Slovene environment.

KEY WORDS

public passenger transportation, ropeway transportation subsystem, capacity

1. INTRODUCTION

Definition

The real capacity of a ropeway transportation system refers to a maximum number of passengers that may be carried per temporal unit by a certain ropeway transportation system under provided conditions which also include comfort for passengers and transportation safety in the entire system of a mountain resort.

Description of research problems

The ropeway transportation subsystem is part of a uniform transportation system that, thanks to a special transport technology, performs its task in mountainous regions that are otherwise hardly accessible. The subsystem in question is dynamic, open and stochastic. However, it may also be dealt with separately, i.e. as an independent system in system analysis. As a rule, the largest delivery ropeways (endless cableways, gondola cableways or ropeways) functioning throughout the year are part of the public transport system. Other facilities of the ropeway transportation system (chairlifts, ski lifts) usually carry out the service transportation task within the framework of a certain mountain resort.

Any ropeway transportation system (subsystem) includes the following elements:

- ropeway infrastructure (ropeway facilities)
- sports infrastructure (ski slopes, sport and recreation facilities) and indirectly also
- tourist infrastructure (tourist and catering facilities).

For each of the elements of the ropeway transportation subsystem there are formulas for calculating theoretical and/or practical capacity. The formulas take into account only some most influential factors of single system elements. In the theory and practice of the ropeway transportation system there is no method that would independently consider all influential factors. It should be noted that all the influential factors cannot be empirically assessed, although some attempts of empirical assessment of single influential factors have already been made [1], [2].

Purpose and objective of research

With the intention of examining the factors producing an effect on the real capacity of the ropeway transportation system, some in-depth analyses in this scientific and research field were made at Road and Traffic Centre of Department of Transportation Engineering, Faculty of Civil Engineering, University of Maribor. The analyses were made within the research framework of the Development of ropeway transportation system in the Republic of Slovenia [3]. The research was ordered both by the Ministry of Science and Technology and the Ministry of Transport and Communications of the Republic of Slovenia.

The research objective was to set an empirical link between the two variables that are seemingly not interconnectable: *Qd* referring to the total number of passengers carried by a ropeway transportation system [the number of passengers per year] and *Ct* referring to the overall theoretical capacity of all the ropeway facilities which perform their transportation task in the system being dealt with [the number of passengers per hour].

Research hypothesis

The real capacity of a ropeway transportation subsystem is a feature of ropeway transportation systems, which indicates development harmonisation level of all the single subsystem elements of the ropeway transportation systems in the mountain resorts.

2. REAL CAPACITY OF A ROPEWAY TRANSPORTATION SUBSYSTEM

The real capacity of a ropeway transportation system depends on:

- overall theoretical capacity of all the ropeway facilities (*Ct*) in a system [the passengers carried per hour];
- connection mode and/or single facility position in a system (either consecutive or parallel position), A_1;
- the extent of sports infrastructure available for use (ski areas in hectares, sports facilities), A_2;
- ski area configuration (ski-trail difficulty levels), A_3;
- ski area layout mode (parallel ski trails, interwoven ski trails), A_4;
- the share of individual types of users of sports infrastructure used according to the users' experience (amateurs, both less successful and successful recreation skiers, sport skiers), A_5;
- the share of long-staying and/or occasional guests in mountain resorts, A_6;
- the comfort (A_7) and safety (A_8) degrees anticipated by all transport users in a ropeway transportation system measured both by the number of people being on transportation areas and delays caused by the throngs of people standing in front of ropeway facilities, etc. (A_n).

Generally, the real capacity of a ropeway transportation system could be put down as follows:

$$Cr = Cr\,(Ct, A_i;\, i = 1, \ldots, n) \qquad [1]$$

2.1 Method

Since all the parameters described cannot be empirically assessed, the method of model analysis of the ropeway transportation system in the neighbouring Republic of Austria was employed to attain the objective set. Austria prides itself on its long-standing tradition in the field of ropeway engineering. In O.I.T.A.F., Austria is the leading country that has a strong impact both on ropeway engineering and technology, and on organising the ropeway transportation also within the framework of European Commission for Transport (ECT). The Austrian model of the ropeway transportation system is characterised by

- a high level both of technical and technological system efficiency,
- co-ordinated operation of different elements of ropeway transportation system within the framework of mountain resorts,
- a co-ordinated offer of services provided by other subsystems of mountain resorts.

These features result from an effect of the open market for goods and services and from an effective role of the state in this economically extremely important field of tourism.

In co-operation with the Austrian Ropeway Engineering Association (Fachverband der Seilbahnen) of the Austrian Chamber of Commerce (Wirtschaftskammer Österreichs) in Vienna, we conducted a survey among some evenly selected mountain resorts in Austria by post. The sample included 15 Austrian mountain resorts of large, moderate and small size. Besides general data, we asked for the overall theoretical capacity of all the ropeway facilities (*Ct*) and the total number of passengers carried by a ropeway transportation system (*Qd*).

The data we gathered were statistically processed and by means of the regression method we ascertained the interconnectivity among the variables in question.

In the case of stabile ropeway transportation system the real capacity of ropeway transportation (*Cr*) is equal to the total number of passengers carried by a ropeway transportation system (*Qd*). Their ratio *Ka*, however, indicates the level of harmony of single system elements in a mountain resort.

2.2 Survey results

11 mountain resorts or 74 % of interviewees answered the questionnaire in full. Table 1 illustrates the survey results.

There were 3,253[1] ropeway facilities, i.e. 314 main ropeways, 437 minor ropeways (chairlifts) and 2,484 ski lifts operating on the territory of the Republic of Austria in 1997. Their overall capacity exceeded 3,200,000 passengers per hour. In winter season only, they all carried more than 440 million passengers. With regard to the total number of facilities, the sample that has been analysed represents 8 % of all the facilities in Austria. Regarding the overall capacity of the ropeway infrastructure, the given sample, however, represents 10.4 % of the entire Austrian offer. As regards the number of the passengers carried, the given sample represents 15.9 % of all the passengers carried in the neighbouring Republic of Austria.

The statistical analysis was made for the cases of linear, logarithmic, potential, exponential and polynomial regression under condition that

$$Ct = 0 \Rightarrow Cr = 0. \qquad [2]$$

Table 1: Basic characteristics of ropeway infrastructure in Austrian mountain resorts

Mountain resort	Height above sea level Lower position	Height above sea level Upper position	Length of trails [in km]	Total number of facilities	Ct [pers. per hour]	Qd [pass. in 1997]
Baerenalm Hinterstoder	660	1,150	6	3	150	110,370
Feuerkogel - Ebensee	460	1,680	12	7	4,500	720,000
Semmering Hirschenkogel	1,000	1,350	13.5	3	5,320	1,650,000
Lienz Zettesfeld	670	2,290	40	12	11,000	2,500,000
Schruns	700	2,400	35	13	13,000	3,850,000
Gerlitzen Sattendorf	1,000	1,911	25	14	1,800	4,200,000
Wagrain	650	2,000	40	20	56,000	5,026,747
Flachau	950	1,800	45	20	23,893	6,000,000
Schladming Planai	800	1,894	52	26	33,000	7,000,000
Kitzbuechel Bergbahn	800	2,000	180	60	77,000	15,530,000
Lech	1,450	2,444	260	84	113,351	24,000,000
Total sample				262	339,014	70,587,117

Both logarithmic and exponential regression was discarded due to irrelevance of results (correlation ratio is $R^2 < 0.5$). Some relevant results were achieved in the cases shown in Table 2.

Table 2: Regression analysis results

Regression type	General form	Regression function	R
Potential regression	$y = a \cdot x^b$	$y = 4815.7 \cdot x^{0.6083}$	0.8171
Linear regression	$y = a \cdot x$	$y = 195.24 \cdot x$	0.8881
Second degree polynomial regression	$y = a_2 \cdot x^2 + a_1 \cdot x + a_0$	$y = 0.0005 \cdot x^2 + 149.57 \cdot x$	0.8981

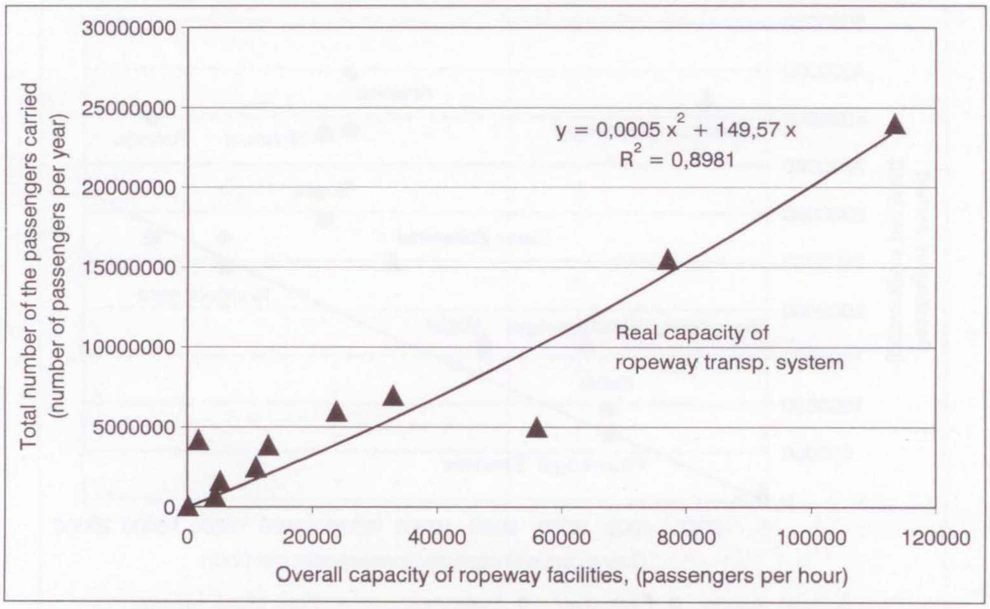

Figure 1: Quadratic polynomial regression on the overall capacity of ropeway facilities *Ct* (independent variable) and the total number of passengers carried by a transportation subsystem *Qd* (dependent variable)

The results obtained with linear and/or polynomial regression are sufficiently accurate to be used for applications in practice.

The function [1] being looked for runs in linear form as follows:

$$Cr = 195.24\,Ct \quad [3]$$

and/or

$$Cr = 0.0005\,Ct^2 + 149.57\,Ct \quad [4]$$

in the case of the second degree polynomial regression.

Figure 1 illustrates results of quadratic polynomial regression.

The assertion based on linear regression is worded as follows:

On the assumption that comfort for passengers, safe use of ropeway facilities and harmonised development of a ropeway transportation subsystem with other subsystems within the systems of mountain resorts are ensured, the ropeway transportation system of an overall capacity of 1,000 passengers per hour should carry on the average 200,000 passengers per year.

The ratio between the actual total number of the passengers carried (Qd) in a mountain resort and the expected real capacity of the ropeway transportation subsystem (Cr) determines the level of harmony of single system elements at mountain resorts.

It has been found out that development harmonisation is provided when

$$Ka = \frac{Qd}{Cr} \approx 1 \quad [5]$$

where Ka is the harmonisation ratio [-].

Table 3: Comparison of the real capacity model of the ropeway transportation subsystem with characteristics of the major Slovene mountain resorts

Mountain resort	Ct(pass. per hour)	Cr (pass. per year)		Qd (pass. per year)		Ka			
		lin.reg.	quad.reg.	average	max.	aver. /lin.	max. /lin.	aver. /quad	max. /quad
Vogel	8,256	1,611.901	1,268,931	1,539,626	1,658,207	0.96	1.03	1.21	1.31
Kanin	4,650	907,866	706,312	944,944	962,425	1.04	1.06	1.34	1.36
Kr. Gora	15,902	3,104,706	2,504,899	2,429,138	2,728,609	0.78	0.88	0.97	1.09
Krvavec	12,222	2,386,223	1,902,733	3,857,373	4,464,696	1.62	1.87	2.03	2.35
Mar.Poh.	18,006	3,515,491	2,855,265	2,726,388	3,968,207	0.78	1.13	0.95	1.39
Rogla	12,970	2,532,263	2,024,033	2,929,067	3,815,700	1.16	1.51	1.45	1.89
Total						1.05	1.25	1.33	1.56

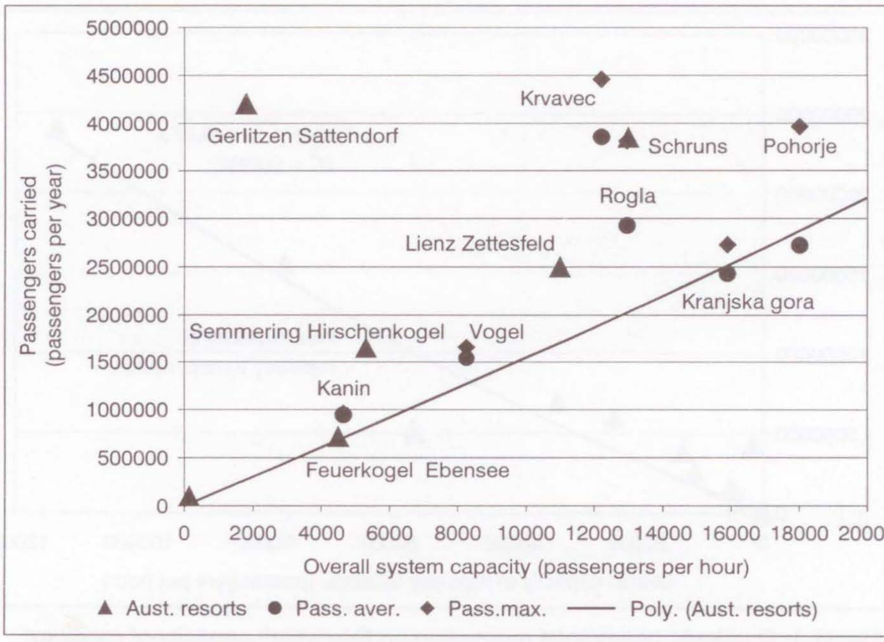

Figure 2 - Comparison of the real capacity model of the ropeway transportation subsystem with characteristics of the main Slovene mountain resorts

3. TESTING THE RESULTS OF RESEARCH IN THE MAJOR MOUNTAIN RESORTS OF THE REPUBLIC OF SLOVENIA

Table 3 and Figure 2 show the results of comparing the characteristics of the ropeway transportation subsystems in the main Slovene mountain resorts with the model represented.

Table 3 and Figure 2 indicate that, on the average, the ratio between the real capacity (expected according to the model) of the linear regression-based ropeway transportation system and an average number of the passengers carried over a three-year period from 1995 to 1997 is Ka = 1.05. However, taking into account only the year with the highest number of passengers carried, Ka is 1.25. When considering quadratic regression, the ratios are higher. This indicates that single system elements of mountain resorts are not well harmonised.

Some major oscillations were noticed among the main Slovene mountain resorts whose systems were analysed. The most obvious departure from the model was noticed in the case of the RTC Krvavec where twice as many passengers were carried in comparison with the model. The reason for this is chiefly the consequence of unbalanced development both of ropeway and tourist infrastructure, and a typical alpine position of the ski areas accessible by only one endless gondola cableway.

The scientific hypothesis that has been set is confirmed by the above evidence and the research objective is attained.

4. CONCLUSION

The method for assessing the real capacity of the ropeway transportation system has proved to be a very simple, accurate and effective instrument for evaluating the development harmonisation level of single elements in a system of mountain resorts. The sphere of application is general.

The comparison of research results with the actual state of the Slovene ropeway transportation system has indicated that the main Slovene mountain resorts with their existing ropeway infrastructure are capable of carrying up to 30 % more passengers than comparable Austrian mountain resorts (according to the model given). The reason for this should be looked for in the under-equipped Slovene mountain resorts regarding their ropeway infrastructure, because most passengers (averaged 65 %) are carried at weekends and on holidays due to fewer long-staying guests. The weekend skiers cause long waiting periods in queues in front of ropeway facilities.

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POVZETEK

V sistemu gorskih športno turističnih centrov ima izjemno pomembno vlogo žičniški prometni podsistem. Zanj je značilna izjemna prepletenost medsebojnih vplivov posameznih elementov sistema. S ciljem zagotavljanja trajnostno usklajenega razvoja celotnega sistema gorsko turističnih centrov je bila v okviru raziskav s tega področja v Centru za ceste in cestni promet na Oddelku za promet, Fakultete za gradbeništvo Univerze v Mariboru določena realna kapaciteta žičniškega prometnega sistema. Izkazalo se je, da je izjemno uporabna kot pokazatelj stopnje usklajenosti razvoja posameznih elementov obravnavanega sistema.

V članku so prikazana temeljna izhodišča, metoda in rezultati raziskovanja tega področja ter rezultati prenosa novih znanj v slovensko okolje.

NOTES

1. The datum refers to the year 1995. According to official data, the total number of facilities did not increase, because major investments were made in streamlining the existing facilities, in increasing transport capacities and not in building new ones.

LITERATURE

[1] *Österreichisches Seilbahnkonzept*, Österreichisches Institut für Raumplanung, Wien 1978

[2] **Doppelmayr**: *Denkanstösse zur Funktionserfüllung von Einseilumlaufbahnen, Projektierung und Konstruktion im Sicherheitsregelkreissystem, basierend auf der Analyse von Vorfällen*, Wolfurt, September 1997

[3] Ropeway transportation system development in the Republic of Slovenia, Road and Traffic Centre of Faculty of Civil Engineering, University of Maribor, ordered by Ministry of Science and Technology and the Ministry of Transport and Communications of the Republic of Slovenia, June, 1999