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APPLICATION OF ORDINAL REGRESSION MODEL TO ANALYZE SERVICE QUALITY OF RIGA COACH TERMINAL

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Abstract. The considered problem has arisen as a result of collaboration with Riga Coach Terminal (*Rīgas Starptautiskā Autoosta*) authorities. Recent studies of the role of buses and coaches seem to confirm the already excellent safety, environmental and social record of bus and coach transport. In Latvia this mode of transport is in competition with railway (and also private cars) that's why the quality of services is very important from all points of view. In authors' previous researches different methods were applied to estimate functional form between overall quality of service and explanatory variables included questionnaire items related to the satisfaction accessibility (availability), information, time characteristics of service, customer service, comfort, safety, infrastructure and environment at Riga Coach Terminal. Such kind of model allows estimating influence of particular quality indicators on the overall quality assessment and simplifying the monitoring of quality indicators. In the given work ordinal regression method has been used to model the relationship between the ordinal outcome variable, e.g. estimates of overall quality of service – y_i (these estimates are made on the basis of (1÷5) scale), and the 22 particular attributes of quality distributed on the mentioned above 7 groups. The main decisions involved in the model building for ordinal regression determine, which particular attributes should be included in the model, and choose the link function (e.g. *logit* link or complementary *log–log* link) that demonstrates the model appropriateness. The model fitting statistics, the accuracy of the classification results, and the validity of the model assumption, e.g., parallel lines, have been assessed for selecting the best model. The model was done on the basis of results of questionnaire of transport experts, which had been fulfilled in spring 2009. In total 44 questionnaires have been returned, however some questions remained without an answer; that's why different methods of data imputation have been applied to substitute skips in dataset and few models have been constructed for selecting the best one.

Keywords: terminal, quality of service, ordinal regression, link function, transport.

Introduction

There has been an increasing emphasis on the study of service quality in different companies and organizations, providing various services, based on the fact that service quality has a direct impact on business success. The investigation surveys provide administration with real pictures of the key issues perceived by their customers. Consequently, the study results from the questionnaire surveys have been used as feedback information to help top management enhance the quality of services.

Riga Coach Terminal (*Rīgas Starptautiskā Autoosta*) being a leader in the area of passenger bus transportation services in Latvia provides the international, intercity and regional trips. Recent studies on the role of buses and coaches seem to confirm the already excellent safety, environmental and social record of bus and coach transport. In Latvia this mode of transport is in competition with railway (and private cars too) in Latvia that's why the quality of services is very important from the all points of view (Gromule, Yatskiv 2007).

When examining literature it becomes clear that it is not the only approach to measuring service quality. But, it is accepted that the quality of service is usually a function of several quality factors (attributes) and determining of each factor weight is one of the 'corner-stones' of quality (Gromule *et al.* 2008; Yatskiv *et al.* 2009).

Authors have used different statistical methods to analyze the quality of service. These methods include descriptive statistics, correlation and regression analysis, theory of linear composite indicator (Yatskiv *et al.* 2010; Andronov *et al.* 2010).

Regression methods such as linear, logistic, and ordinal regression are useful tools to analyze the relationship between multiple explanatory variables, e.g., partial quality attributes, and dependent variable, e.g., overall quality of service. These methods also permit researchers to estimate the magnitude of the effect of the explanatory variables on the outcome variable. If researchers wish to study the effect of explanatory variables on all levels of the ordered categorical outcome, an ordinal regression method must be appropriately chosen to obtain valid results (Chen, Hughes 2004).

The paper presents a brief theoretical justification of the method of analysis, e.g., ordinal *logit* regression, two major link functions are considered (*logit* and *cloglog* links).

The PC-based version 17.0 of the SPSS commands has been used to perform the ordinal regression analysis (Kirkpatrick, Feeney 2010).

The step-by-step procedures for building, evaluating, and interpreting the ordinal regression model for describing relationship between overall quality of service, and the 22 particular attributes of quality have been illustrated in this research. The *logit* and the *cloglog* links were chosen to build models based on the distribution of ordinal outcome, ether evenly distributed among all categories or clustered around high categories. It has been concluded that models in *cloglog* link are not applicable to existing data, i.e., this says that transport experts do not tend to higher categories in their assessment of the quality of the passenger terminal. Finally, the best model has been chosen among all candidate models based on the model fitting statistics, the accuracy of the classification results, and the validity of the model assumptions, and the principle of parsimony.

1. Ordinal Regression Model

Many variants of regression model for analyzing ordinal response variables were being developed and described during the past years. Ordinal regression model is embedded in the general framework of generalized linear models. Different models result from the use of different link functions.

In ordinal regression analysis two major link functions, e.g., *logit* and *cloglog* links are used to build specific models. There is no clear-cut method to distinguish the preference of using different link functions. However, the *logit* link is generally suitable for analyzing the ordered categorical data evenly distributed among all categories. The *cloglog* link may be used to analyze the ordered categorical data when higher categories are more probable (SPSS 1999).

The ordinal regression model may be written in the form as follows if the *logit* link is applied:

$$f\left(\gamma_j\left(X\right)\right) = \log\left(\frac{\gamma_j\left(X\right)}{1-\gamma_j\left(X\right)}\right) =$$

$$\log\left(\frac{P\left\{Y \le y_j / X\right\}}{P\left\{Y > y_j / X\right\}}\right) = \alpha_j + \beta X, \quad j = 1,\ 2,\ \ldots, k-1;$$

$$\gamma_j\left(x\right) = \frac{e^{\alpha_j + \beta X}}{1 + e^{\alpha_j + \beta X}},$$

where: j indexes the cut-off points for all categories (k) of the outcome variable (this model is the well-known proportional odds (PO) model (McCullagh 1980), also called ordinal logistic model (Scott *et al.* 1997), cumulative odds model (Armstrong, Sloan 1989; Greenland 1994), or McCullagh's grouped continuous model (Greenwood, Farewell 1988). The number of different names for the same models causes unnecessarily much confusion about ordinal regression models). It is assumed that for the considered link function f the corresponding regression coefficients are equal for each cut-off point j. The adequacy of this 'equal slopes assumption' has to be evaluated carefully before this model can be applied (Bender, Benner 2000). If multiple explanatory variables are applied to the ordinal regression model, βX is replaced by the linear combination of $(\beta_1 X_1 + \beta_2 X_2 + \ldots + \beta_p X_p)$. The function $f(\gamma_j(X))$ is called the link function that connects the systematic components (i.e. $\alpha_j + \beta X$) of the linear model. The alpha α_j represents a separate intercept or threshold for each cumulative probability. The threshold (α_j) and the regression coefficient (β) are unknown parameters to be estimated by means of the maximum likelihood method (Bender, Benner 2000).

The ordinal regression model may be written in the form as follows if the complementary log-log (*cloglog*) link is used to create the model

$$f\left(\gamma_j\left(X\right)\right) = \log\left(-\log\left(1-\gamma_j\left(X\right)\right)\right) =$$

$$\log\left(\log\left(\frac{P\left\{Y = y_j / X\right\}}{P\left\{Y > y_j / X\right\}}\right)\right) = \alpha_j + \beta X, \quad j = 1,\ 2,\ \ldots, k-1;$$

$$\gamma_j\left(X\right) = 1 - e^{-e^{\left(\alpha_j + \beta X\right)}},$$

where: j indexes the cut-off points for all categories (k) of the outcome variable. The term of the complementary function comes from $(1 - \gamma_j(X))$. The ordinal regression model with the *cloglog* link is also called the proportional hazard model because the relationship between the explanatory variables and the ordinal outcome is independent of the category (Bender, Benner 2000).

2. Study Results

The models were constructed on the basis of results of questionnaire of 44 transport experts, which was fulfilled in spring 2009. Respondents were the high-qualified transport specialists. The questionnaire included 7 groups of questions concerned the following groups of quality particular attribute:

- Accessibility (availability):
  - *X*1 – accessibility for external participants of traffic;
  - *X*2 – accessibility for terminal passengers;
  - *X*3 – ticket booking.
- Information:
  - *X*4 – general information in terminal;
  - *X*5 – information about trips in positive aspect;
  - *X*6 – information about trips in negative aspect.
- Time characteristics of service:
  - *X*7 – duration of trip;
  - *X*8 – punctuality;

- ◦ *X*9 – reliability/trust;
- ◦ *X*10 – bus time schedule.

- Customer service:
  - ◦ *X*11 – customer trust to terminal employees;
  - ◦ *X*12 – communication with customer;
  - ◦ *X*13 – requirements to employees;
  - ◦ *X*14 – physical services providing;
  - ◦ *X*15 – process of ticket booking;
  - ◦ *X*16 – services provided by bus crews during boarding/debarkation.
- Comfort:
  - ◦ *X*17 – cleanness and comfort in terminal premises and on terminal square;
  - ◦ *X*18 – additional opportunities/services providing in coach terminal.
- Safety:
  - ◦ *X*19 – protection from crimes;
  - ◦ *X*20 – protection from accidents.
- Infrastructure and environment:
  - ◦ *X*21 – dirtying, its prevention;
  - ◦ *X*22 – infrastructure.

Totally there were 22 particular attributes of quality distributed on these 7 groups. Furthermore, the overall quality of service has been evaluated; as well as particular attributes of quality the overall quality service has been estimated on a scale 1÷5. In total 44 questionnaires have been returned but some questions remained without the answer in three questionnaires. Also there were gaps in the data pertaining to the partial attributes of quality. The large percent of cells with missing data could lead to an inaccurate estimation. Therefore it has been decided to apply different methods of data imputation to substitute skips in dataset, because excluding missing data from the consideration would be unwise due to the fact that sample is too small.

There are many classical approaches for work with incomplete data set. The simplest existing methods have been implemented actually in all application program packages for statistical data processing such as unconditional mean imputation and regression imputation. But the most simple is not always the most effective; especially for this sample. That's why authors have tried different imputation methods.

The package R was used to restore skips in data set. The main condition for imputation was that the values must be integers, so some methods did not yield the desired results. Table 1 contains results of missing data imputation by different methods.

As we can see from the Table 1 only one method has given appropriate data set (Multivariate Imputation by Chained Equations). All future investigations will be considered based on sample received using the first method, e.g., Multivariate Imputation by Chained Equations.

Let's consider the distribution of transport expert's ratings: 25% assessed the overall quality of service by 3 points; 65.9% – by 4 points, 9.1% – by 5 points.

The complete model, e.g., the model with full set of factors, analyzed 44 questionnaires, with no items with missing data. The result of this model in the *logit* link, as well as in the *cloglog* link did not need to be presented in the paper because the model assumption of parallel lines was violated. PLUM procedure was failed; the maximum likelihood estimates did not exist. Validity of the model fit was uncertain.

Table 1. Results of missing data imputation by different methods

Nr.	Method	Results
1.	Multivariate imputation by chained equations (MICE)	Appropriate data set
2.	Expectation maximization (EM)	Sample is not enough (too many variables)
3.	Linear discriminant analysis	Error of applying method for this sample
4.	*K*-nearest neighbor (KNN)	Not categorical data
5.	Bayesian linear regression	Not categorical data

In search of the best model since the *logit* link and *cloglog* link in the ordinal regression analysis are not capable of selecting a subset of significant explanatory variables by means of automatic model building methods such as stepwise and back elimination procedures in SPSS, authors are obliged to rely on their own intuition and experiences to select a subset of the important or significant explanatory variables in the model.

To construct the best model the following strategy has been considered: from 22 non-significant factors those are selected, which have *p*-level up to 0.7, namely *X*22 (*sig.* = 0.201) – Infrastructure, *X*20 (*sig.* = 0.46) – Protection from accidents, *X*16 (*sig.* = 0.428) – Services provided by bus crews during boarding/debarkation, X11 (*sig.* = 0.529) – Customer trust to terminal employees, X8 (*sig.* = 0.531) – Punctuality, *X*19 (*sig.* = 0.567) – Protection from crimes, *X*9 (*sig.* = 0.628) – Reliability/trust, *X*3 (*sig.* = 0.655) – Ticket booking. It is noteworthy that the applying Backward stepwise procedure exactly the same variables are obtained even up to a sign factor. Unfortunately model with the 'most significant' 8 factors in the *logit* link as well as in the *cloglog* link also proved inadequate and inapplicable for further analysis because the model assumption of parallel lines was violated, the maximum likelihood estimates did not exist and validity of the model fit was uncertain. Model was still too complex. Further excluding non-significant factors one by one led to the first adequate model in the *logit* link with the following factors: *X*22 (*sig.* = 0.009) – Infrastructure, *X*11 (*sig.* = 0.002) – Customer trust to terminal employees and *X*8 (*sig.* = 0.066) – Punctuality. The model assumption of parallel lines in the model with 3 factors was not violated (e.g., χ^2 = 1.619 with df = 3 and p = 0.655), the results of the Pearson's chi-square test (e.g., χ^2 =37.919 with df = 3 and p = 0.000) indicated that we could reject null hypothesis that the model without predictors was as good as the model with the predictors. The three pseudo R squares – McFadden (0.513), Cox and Shell (0.578), and Nagelkerke (0.710) were high. Hence, the model with 3 factors in *logit* link was a good model.

Let's interpret results of estimation. Variable *X*8 is responsible for punctuality that is an integral attribute of qualitative service, if punctuality is evaluated highly this suggests that the passenger terminal cares about its customers and has fulfilled its obligations. Variable *X*11 (Customer trust to terminal employees) belongs to the group 'Customer Service'. High-quality customer service is a very important component of service, that's why including variable *X*11 to the model, is logical. Consequently, we can conclude that the increase in confidence and conditions of service will significantly improve the overall assessment. The last variable *X*22 associated with the state of Coach Terminal infrastructure also significantly affects the overall quality assessment.

It should be noted that due to Forward stepwise procedure applied to full set of 22 factors only two were selected as significant ones: *X*22 (*sig.* = 0.001) –Infrastructure, *X*11 (*sig.* = 0.000) – Customer trust to terminal employees.

Table 2 shows estimation results of model with 3 factors.

The cross-tabulating method was used to categorize the classified and the actual responses into a 3 by 3 classification table. Table 3 contains accuracy of the classification for response category with estimated parameters for regression model with 3 factors in *logit* link.

Table 2. Explanatory variables associated with the overall quality of service based on the model with 3 factors in the *logit* link

Item name	*Logit* link	
	Regression coefficients	*p*-value
*X*8 (Punctuality)	1.579	0.066
*X*11 (Customer trust to terminal employees)	4.180	0.002
*X*22 (Infrastructure)	1.675	0.009

Table 3. Accuracy of the classification for response categories based on the regression model in *logit* link with 3 factors

Actual response category (observed *Y*)	Accuracy	Classified response category		
		3	4	5
3	72.7%	8	3	0
4	89.7%	2	26	1
5	25.0%	0	3	1
Total	66.8%	10	32	2

The model demonstrated fairly high prediction accuracy (66.8%) for all three categories combined.

Further, based on the results obtained by the Forward stepwise procedure for full set of factors, model with two most significant factors, e.g., *X*22 – Infrastructure, *X*11– Customer trust to terminal employees was constructed in *logit* link. The model assumption of parallel lines in the model with 3 factors was not violated (e.g., χ^2=1.579 with *df* = 2 and p = 0.454), the results of the Pearson's chi-square test (e.g., χ^2 = 34.085 with *df* = 2 and p = 0.000) indicated that we could reject null hypothesis that the model without predictors is as good as the model with the predictors. The three pseudo *R* squared – McFadden (0.461), Cox and Shell (0.539), and Nagelkerke (0.633) were high. Hence, the model with 2 factors in *logit* link was a good model.

The same model with two factors in *cloglog* link failed to provide some adequate results.

Table 4 contains accuracy of the classification for response category with estimated parameters for regression model with 2 factors in *logit* link.

Despite the fact that the model with two factors shows higher accuracy (70.3% versus 66.8%), still researchers have decided to keep as the best model the model with 3 factors because all screening criteria are higher, and also variable *X*8 (Punctuality) seems to be rather important in assessing the quality of service in passenger terminal.

Table 4. Accuracy of the classification for response categories based on the regression model in *logit* link with 2 factors

Actual response category (observed *Y*)	Accuracy	Classified response category		
		3	4	5
3	72.7%	8	3	0
4	93.1%	2	27	0
5	0%	0	4	0
Total	70.3%	10	34	0

Another alternative how to handle the issue of missing data is related to the possibility of combining the individual items into the 'factors' and using the item average score. We will form 7 new variables corresponding to 7 groups of attributes (categories of questions). Grouping of the initial attributes and calculation of new values on the basis of an average leads to a replacement of categorical variable x_i (i = 1, .., 22) by interval w_l (l = 1, .., 7).

The complete model with grouped data analyzed 44 questionnaires, with no items with missing data. The result of this model in the *logit* link, as well as in the *cloglog* link did not need to be presented because the model assumption of parallel lines was violated. PLUM procedure was failed; the maximum likelihood estimates did not exist. Validity of the model fit was uncertain.

From 7 non-significant grouped factors it was decided to choose the most significant ones: *W*4 – Customer Service (*sig.* = 0.191), *W*5 – Comfort (*sig.* = 0.135) and *W*6 – Safety (*sig.* = 0.206). Estimation results of the model constructed with 3 grouped factors in *logit* link are showed next. The model assumption of parallel lines in the model with 3 grouped factors is not violated (e.g., χ^2 =3.130 with *df* = 3 and p = 0.372), the results of the Pearson's chi-square test (e.g., χ^2 =24.098 with *df* = 3 and p = 0.000) indicate that we can reject null hypothesis that the model without predictors is as good as the model with three pseudo *R* squares – McFadden (0.326), Cox and Shell (0.422), and Nagelkerke (0.518) are fairly high. Hence, the model with 3 grouped factors in *logit* link is a good model.

Because of one variable, namely *W*6 – Safety, was not significant (*sig.* = 0.313) it was decided to exclude this factor, and to build one more model with 2 grouped factors, namely *W*4 – Customer Service (*sig.* = 0.022) and *W*5 – Comfort (*sig.* = 0.069).

The same models with 3 grouped factors and 2 grouped factors in *cloglog* link failed to provide some adequate results.

Estimation results of model constructed with 2 grouped factors in *logit* link are showed below.

The model assumption of parallel lines in the model with 2 grouped factors is not violated (e.g., $\chi^2 = 1.297$ with $df = 2$ and $p = 0.523$), the results of the Pearson's chi-square test (e.g., $\chi^2 = 23.095$ with $df = 2$ and $p = 0.000$) indicate that we can reject null hypothesis that the model without predictors is as good as the model with the predictors. The three pseudo R squares – McFadden (0.313), Cox and Shell (0.408), and Nagelkerke (0.502) are fairly high. Hence, the model with 2 grouped factors in *logit* link is also a good model comparing with previous one.

Table 5 contains accuracy of the classification for response category with estimated parameters for regression model with 3 grouped factors in *logit* link.

Table 5. Accuracy of the classification for response categories based on the regression model in *logit* link with 3 grouped factors

Actual response category (observed *Y*)	Accuracy	Classified response category		
		3	4	5
3	72.7%	8	3	0
4	96.6%	1	28	0
5	0%	0	4	0
Total	74.7%	10	34	0

The model demonstrated high prediction accuracy (74.7%) for all three categories combined.

It is noteworthy that the classification accuracy based on the model with 2 grouped factors is absolutely identical to classification results based on the model with 3 grouped factors.

Due to forward stepwise procedure applied to full set of 7 grouped factors only one has been selected as significant one: *W*4 – Customer Service. Adequacy of the ordinal regression model with one grouped factor in *logit* link has been confirmed by all criteria, but the accuracy of the model is not high enough – 60.4%.

Model with 2 grouped factors has been recognized as the best among all candidate models with grouped factors.

Conclusions

In the given work the ordinal regression method has been used to model the dependency between the overall quality of service and the particular attributes of quality distributed on 7 groups, namely satisfaction accessibility (availability), information, time characteristics of service, customer service, comfort, safety, infrastructure and environment at Riga Coach Terminal. The outcome variable for overall quality of service has been measured on an ordered, categorical, and five points' scale – from 1 to 5. The reduced model with 3 factors with the *logit* link became the best model based on the screening criteria – the validity of model assumption, the fitting statistics (e.g., Person's chi-square and pseudo *R* squares), the accuracy of the classification results, the principle of parsimony, and the stability of parameter estimation. The research findings indicated Infrastructure, Customer trust to terminal employees and Punctuality were significantly associated with the overall quality of service. Analyzing grouped variables two 'factors' have been identified as significant – Customer Service and Comfort. Grouping data loses some of the detail but provides the researcher with additional information.

Much of the time and energy has been devoted to developing candidate models, checking the model assumptions, assuring the model goodness of fit, and consequently selecting the best model for passenger terminal.

Problem of missing data has been handled by applying different imputation methods.

It is concluded that *cloglog* link function is not suitable for applying to existing data, i.e., this says that transport experts do not tend to higher categories in their assessment of the quality of the passenger terminal.

The knowledge gained from this study would be beneficial to the Riga Coach Terminal management and its customers too. The goal was to obtain information from transport experts for benchmarking that could be helpful to top managers of passenger terminal for improving level of services.

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