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Value creation of road infrastructure networks: A structural equation approach



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ABSTRACT

Although road agencies need to provide road infrastructure that is beneficial for road users, little is known about how the activities of the agencies influence the value creation of road infrastructure. From a service-dominant logic perspective, the importance of road maintenance and traffic management activities for the contribution of road infrastructure to the value-creation process of road users is investigated. Road agencies facilitate the value creation of road users by maintaining, upgrading or renewing road infrastructure, the provision of information about the current traffic situation, possible redirection routes in case of traffic jams, and suggestions for appropriate driving behavior. Based on a structured questionnaire, data were collected among motorists in Singapore and analyzed by means of a partial least square modeling approach. The analysis revealed that road cleanliness and road evenness have a significant effect on the experience of road maintenance. Important and significant indicators for the experience of traffic management are the clarity of road signs and the efficiency of traffic redirection. A main conclusion of the research is that for traffic-intensive networks, both road maintenance and traffic management activities are important contributors to the value creation of road infrastructure with a slightly stronger contribution of traffic management activities. Road agencies need to find appropriate maintenance strategies which reduce and coordinate simultaneous maintenance interventions on the network to such an extent that traffic management activities are able to minimize any considerable loss of traffic flow.

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1. Introduction

In modern society, road infrastructure has become an essential part of daily life. Individual road users, logistic firms, and public transportation agencies expect reliable and safe road infrastructure for traveling from one location to another and transporting goods and people. Road agencies need to properly plan, build, maintain, and operate road infrastructure for it to create value for road users. In recent decades road agencies have started to use performance measures to evaluate the effectiveness and efficiency of their service provision. Besides legal obligations and resource constraints, the increased attention towards the needs of road users has been a main motivation for implementing performance measures (Burde, 2008). Road user satisfaction surveys at the national and regional network levels have become a common tool for identifying deficiencies in road services, defining performance targets and measuring their achievements. Typically, these surveys often asked about the satisfaction with particular outcomes of road agency activities such as quality of road surface or lighting on roads (e.g. Hyman and Heffner, 2003; Huijgen et al., 2006; McKenzie, 2004). However, they pay less attention to how road users experience the services of road agencies and how these experiences influence the value creation of road infrastructure. Knowledge about the experiences of road users with the activities of road agencies and the perceived contribution of these activities to the value creation of road infrastructure are important for two reasons. First, the perspective of road agencies can differ from the perspective of road users in terms of the importance of activity outcomes for the value-creation process of the user (Levinson, 2003; Sinha et al., 2009). As shown by the study of Bonsall et al. (2005), the view of transport professionals on the seriousness of specified road problems for users can deviate from the road users' experiences of these problems. Second, many road agencies mainly rely on physical road conditions as the basis for decisions, which do not necessarily reflect the performance understanding of road users (Osman, 2012). Despite the need for incorporating the performance view of road users in decisions, there are only few attempts linking condition parameters and user perception of road quality (e.g. Giese et al., 2001; Haas and Hudson, 1996), and only quite recently, research has suggested that the experiences of road characteristics and traffic conditions have an influence on the utility of traveling (Ettema et al., 2013). In order to support user-oriented policy decisions on which activities should be constantly upheld or improved and which performance targets should be set, road agencies should not only develop a more thorough understanding of the experiences of road users with agency activities, but should also consider the influence of these experiences on the value that road infrastructure creates for its users.

Given the above, the aim of this research is to shed more light on the role of road agency activities for the value creation process of road users. The research builds upon an earlier study of Ling and Ng (2011), which explored the relationship between activity outcomes and road user satisfaction in

Singapore and found two activity outcomes (cleanliness of roads and efficiency of traffic redirection arising from road works) affecting satisfaction. Based on a structural equation approach, we extend the work of Ling and Ng (2011) by examining the relationship between the road user experience of road agency activities and the value that road users achieve through these activities. More specifically, our aim was to investigate the effect of road user experience with two main activity types: road maintenance and traffic management. Both activity types are central to the service provision of road agencies and can be expected to have a great impact on the value proposition of road infrastructure. It is this notion of value offering which forms the theoretical lens of our research. By adopting the perspective of service-dominant logic (Vargo and Lusch, 2004), we argue that road infrastructure itself does not possess any value but only incorporates value proposition for its users. Whether road infrastructure contributes to the value creation of its users is determined at the moment when the users are driving on the road and experiencing road maintenance and traffic management activities of the road agencies, which are manifested in the performance parameters of road infrastructure such as road condition and traffic flow (cf. Sandström et al., 2008).

The relationship between the experience of road agency activity and the contribution of road infrastructure to the value creation of its users is investigated in the context of Singapore. Singapore is a developed country with a complex network of roads. Being a small country with a large human to land ratio, and, consequently, with relatively high traffic on the roads, Singapore makes a good example for the challenge of providing reliable and safe infrastructure in many densely populated urban regions around the world. The tasks of maintaining and managing Singapore's high-traffic roads are performed by a statutory board called the Land Transport Authority (LTA). In this research we examine the experiences of motorists with the road maintenance and traffic management activities of the LTA and the influence of the activity experience on the value that is created when using road infrastructure. By doing so, the research contributes to the wider debate on stakeholder satisfaction and performance measurement in road infrastructure (e.g. Karlaftis and Kepaptsoglou, 2012; Osman, 2012; Pei et al., 2010; Poister, 1997; Rouse et al., 1997; Talvitie, 1999).

In the next section the structure of the conceptual model used in the research is presented followed by the description of the measurement model applied. Then, the research design is outlined. The paper continues with discussing presentation and discussion of the research results. It finishes with some managerial implications, limitations and recommendations for further studies.

2. Conceptual model

Our research draws upon the service-dominant logic stream of literature which posits that value is created by customers during the consumption of services (Grönross, 2011; Vargo and Lusch, 2004). Value is not purely given by the presence of service attributes for which a customer is

willing to pay, but “arises in the customer's space and through the customer's usage process” (Macdonald et al., 2011). Value emerges from the experience of the customer during usage rather than being embedded in the service itself (Prahalad and Ramaswamy, 2004). It is “an interactive relativistic preference experience” (Holbrook, 2006) and is what customers want to happen in a specific situation and related to a specific purpose or goal (Woodruff and Flint, 2006). This concept of value-in-use implies that firms and other service providers are not able to create predefined value; they only can make value propositions. It is the customer who defines and creates the actual value through the process of consuming the service (Vargo and Lusch, 2004). As a consequence, customer experiences of service activities become crucial for the extent to which a service contributes to the value creation of the customer.

Traditionally, services have been seen as intangible, non-material goods which are rendered through the application of specialized competences of a service provider. These knowledge and skills of the service provider applied during the interaction with the customer influence the value experience of the customer and thus become critical for the customer's value-creation process. However, from the service-dominant logic point of view, services are also released through the use of products without any direct interaction between service provider and customer and emerge from the interaction of a physical device (e.g. mobile phone) and an underlying technical infrastructure (e.g. mobile telephony network) (Sandström et al., 2008). The tangible good represents a resource used by customers for the value-creation process (Grönross and Ravald, 2009). It incorporates value propositions which include the product's functionalities – e.g. what is the product able to do – and its intangibles – e.g. which symbolic meaning does the product possess (Sandström et al., 2008). The product acts as a distribution mechanism for services, which implies that any supplier of tangible and/or intangible goods becomes a service provider (Prahalad and Ramaswamy, 2004).

Typically, road agencies provide two main activity types: road maintenance and traffic management (Huang et al., 2009). Road maintenance includes all activities aimed at restoring or keeping road infrastructure in a desired condition (Worm and van Harten, 1996). It delivers services to road users through road infrastructure, and road users access this service by driving with vehicles on the infrastructure. In other words, road agencies facilitate the value creation of road users by maintaining, upgrading or renewing road infrastructure. The outcome of the road agency's maintenance process is road infrastructure with specific condition parameters which performs services for road users. Road infrastructure is a resource that road users can make use of and integrate into their value-creation processes. For example, the decision of users to take a car for visiting friends at the weekend or a truck for delivering products to customers includes the decision to utilize road infrastructure. For the users, road infrastructure becomes a means to an end. It does not possess any value per se and only incorporates value propositions. The extent to which road users perceive value-in-use of road infrastructure then

depends on their experience of the road agency's maintenance activities manifested in the experienced road condition parameters (Haas and Hudson, 1996). When visiting a friend, the value does not emerge from road infrastructure but from the time spent with the friend. Road infrastructure contributes to the users' value creation by influencing, for example, the time needed to drive to the friend, the costs of traveling, and the stress of riding (Ettema et al., 2013). Bad road conditions can increase the travel time due to reduced speed, lead to higher costs due to higher fuel consumption, and greater stress due to less driving comfort (Sinha and Labi, 2007).

Traffic management – the second main activity type of road agencies – denotes all activities that aim at controlling traffic parameters by changing the intended use of road infrastructure (Meyer, 1999). Like road maintenance, it contributes to the value creation of road users by influencing performance parameters of road infrastructure. However, while road maintenance indirectly provides services through road infrastructure with certain condition parameters, road agencies directly engage with the users through traffic management measures which include the provision of information about the current traffic situation, possible redirection routes in case of traffic jams, and suggestions for appropriate driving behavior. Since the road agencies adjust their traffic management measures to the current traffic patterns which are to some extent a response to previous measures, road agencies and road users interact with each other; they “take actions of some sort that influence the other party's process” (Grönross and Ravald, 2009). Traffic parameters of road infrastructure such as flow, density and speed are outcomes of this interaction. Due to the direct influence on the experience and the value creation process of road users, the road agencies are more than facilitators; they take on the roles of value co-creators. They not only make value propositions but also play an active role in the value-creation process which can have positive or negative consequences for the value formation (Echeverri and Skälén, 2011). For example, rerouting can contribute to the creation of value by preventing road users from being caught in traffic jams and causing stress and unpleasantness (Novaco and Gonzalez, 2009). It can also contribute to the destruction of value if road users perceive traveling longer than usual as incongruent with their expectations (Burde, 2008). For road agencies, it is not only important to interact with the road users but also to understand how individual and collective peculiarities influence the value formation of users.

Conceptually, we propose that road user experience with agencies' road maintenance and traffic management affect the value-in-use of road infrastructure.

3. Measurement model

Our conceptual model suggests that road agencies influence the value-in-use of road infrastructure by applying road maintenance and traffic management activities. Road users experience both activities through the activity outcomes. In the case of road management, these outcomes are

infrastructure condition parameters, whereas the outcomes of traffic management are information and instructions received by road users. We therefore used road users' experiences with infrastructure conditions and obtained information and instructions as indicators forming the experiences with road maintenance and traffic management. We propose that these indicators cause road user experience with the activities of road agencies and that the coalescence of the indicator effects on the model constructs acknowledges the uniqueness and contextual dependency of road user experiences (cf. Grönross and Ravald, 2009). Besides individual and collective differences, the experience will particularly depend on the agency responsible for the infrastructure network and the agency's activities. That also means that removing or adding activity outcomes as formative indicators may change the weights of the indicators and the relationship of the latent constructs in the conceptual model (Cenfetelli and Bassellier, 2009).

In the Singapore context – the focus of this research – the Land Transport Authority (LTA) as the national road agency pays particular attention to the following condition parameters (LTA, 2010b):

- Road evenness

Road evenness is essential for the driving comfort and safety of road users and is achieved by adequate design of the different layers of the road to take the loading so that differential settlement will not occur. To ensure evenness of road surfaces after deterioration, the LTA specifies and controls the maximum long-term allowable settlement in the pavement structure and the differential settlement between any two adjacent points.

- Water ponding

Water ponding is an infrastructure condition which may lead to dangerous situations for road users. LTA tries to prevent water ponding by ensuring road levelness so that surface water can be efficiently drained off. Guidelines state that all external paving must be designed, constructed, and maintained to drain off surface water efficiently to prevent ponding of water, and this includes an effective water drainage system.

- Road cleanliness

In Singapore road infrastructure is kept clean through a three-pronged approach: road cleansing, public education and enforcement of laws (NEA, 2008). Contractors have mechanized the cleansing of public roads such as using mechanical road sweepers and ride-on mechanical pavement sweepers. In terms of education, the key message is that the public should not rely on cleaners to clean up after them. Rather, they should take personal responsibility for holding on to their litter until they find a bin to dispose of it. Anti-littering laws are in place, and strict enforcement is carried out to deter litterbugs.

Indicators for LTA's traffic management include (LTA, 2010a):

- Ease of navigation

Ease of navigation is the possibility of road users to find their way on a road network without much effort, time, and difficulties. The road system would be easy to navigate if it has been planned and designed comprehensively, preferably from the early age of the city.

- Clarity of road signs

The different types of road signs used in Singapore are: regulatory signs, warning signs, and information/directional signs. Road signs need to be suitably located to enable drivers to have sufficient time to react safely. Where necessary, enhanced guidance (traffic sign showing both destination and lane use) are also provided. To ensure that road signs are legible, the LTA requires that they be located at a 95° angle away from the line of a straight highway to avoid the direct reflection from headlamp beams. All signs should also not be blocked by trees, thus, trees should not be planted within 75 m and 45 m in front of signs on expressways and other roads.

- Efficiency of traffic redirection

Traffic redirection is a consequence of road works such as tunneling (e.g. for subways), road widening, drainage deepening or widening, and burying of utility pipes and cables. These road works either reduce the capacity of the road network or require the temporary closure of parts of the network. The traffic must be redirected via other routes and the efficiency of the redirection refers to the amount of time that is needed to take these alternative routes compared to the original route.

It should be noted that other condition parameters (e.g. raveling, potholing) and traffic management parameters (e.g. traffic flow, congestion) may be experienced by road users. However, we do not intend to analyze all potentially possible condition and traffic management parameters. Rather, we investigate those factors that the LTA in Singapore considers important. While keeping the practical relevance for the contextual setting of the research, it still allows us to explore the influence of road maintenance and traffic management activities on the value creation of road infrastructure.

Value-in-use is perceived and evaluated at the moment of consumption (Vargo and Lusch, 2004). It is the evaluation of the service experience (Sandström et al., 2008) which is accumulated over time (Grönross and Ravald, 2009). As discussed above, service provision of road infrastructure and thus value-in-use experience of road users depend on road condition and traffic parameters. Both parameter types are interrelated, since maintenance work needed to restore road conditions can decrease road capacity and impose traffic disturbances to a network. We therefore use two reflective measures as indicators for the value-in-use of road infrastructure: the evaluation of the overall road network performance and the evaluation of the agency's road work coordination. Network performance refers to the influence of condition parameters and work coordination considers the influence of road maintenance work on the service

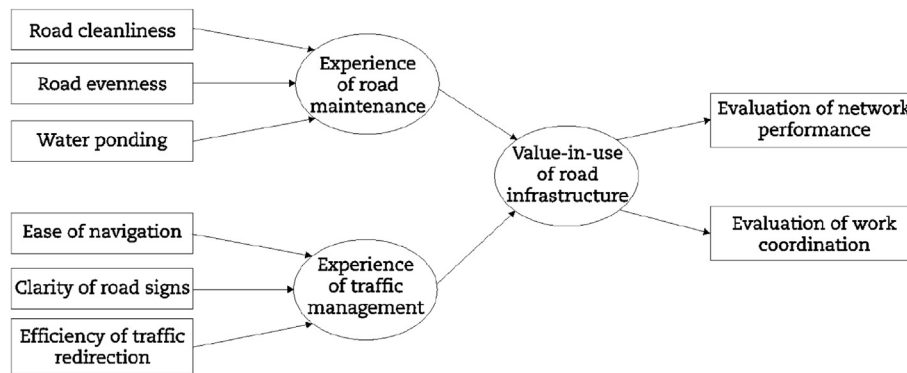


Fig. 1 – Conceptual and measurement model.

provision of road infrastructure. The road users' experience of the services provided by road infrastructure and the extent to which it is beneficial for the road users' value creation process are reflected in their judgment of network performance and work coordination. The conceptual and measurement model is shown in Fig. 1.

4. Research method

4.1. Data collection

The data collection instrument was a specially designed two-part questionnaire. The first part required respondents to provide information about themselves and their driving experience and frequency for the purpose of data classification. The second part sought views about their experience with road maintenance and traffic management activities and value-in-use of road infrastructure. As described above, for measuring road maintenance experience, three formative road condition indicators were used: road evenness, water ponding, and road cleanliness. Respondents were asked to report on their experiences with the three condition parameters on a 10-point Likert scale, where 1 represented 'very uneven/very serious/very dirty', and 10 stood for 'very even/no problem/very clean'. Experience with traffic management activities was measured by the three formative indicators: ease of navigation, clarity of road signs, and efficiency of traffic redirection. Again, the respondents reported on their experience with the three parameters on a 10-point Likert scale, where 1 represented 'very difficult/very unclear/very inefficient', and 10 stood for 'very easy/very clear/very efficient'.

For measuring value-in-use of road infrastructure, two reflective indicators were used. Respondents were asked to evaluate network performance and work coordination on a 10-point scale, where 1 stood for 'very poor/very bad' and 10 represented 'excellent/very good'.

Road users are defined in this study as drivers of motor vehicles (motorists). The population frame for this study comprised motorists in Singapore. Using the standard sample size formula, and the tolerance level of variance or the margin of error set at 0.09, the sampling size was 110. The method of sampling chosen is a combination of convenience sampling

and snowball sampling. These sampling methods were chosen because time taken for conducting the survey is lessened and the response rate is significantly high. However, the limitation is that there is potential for the responses to be biased. The completed questionnaires were checked and it was found that there was no specific pattern of ratings, and respondents had rated on different points of the scale. The questionnaires were distributed through three different methods. The main method of distribution was via email. The other two methods were hardcopy distributions and dissemination using Windows Messenger.

4.2. Data analysis

To estimate our conceptual model, we used structural equation modeling (SEM), which is a second generation multivariate analysis technique. SEM combines both econometric and psychometric perspectives in statistical modeling attempts and allows estimation of simultaneous relationships among unobservable predictor and predicted constructs, characterized by their respective block of measurement items. There are two approaches for estimating structural equation models: covariance-based SEM and variance-based partial least square (PLS) modeling. Covariance-based SEM is a confirmatory approach which tries to minimize the discrepancy between the estimated and sample covariance matrices. Variance-based PLS is a prediction-oriented approach which tries to maximize the explained variance of the endogenous latent variable by applying a series of ordinal least square regressions (Hair et al., 2012a). Since we are interested in explaining and predicting the value-in-use of road infrastructure in Singapore, we adopted the PLS modeling approach for our study. In addition, the PLS approach relaxes some of the assumptions and requirements of covariance-based SEM such as sample size, formative measurements, and normality (Hair et al., 2012b). The data were analyzed with the software program SmartPLS (Ringle et al., 2005).

5. Results and discussion

Of the 110 sets of questionnaires sent out, 53 completed sets from motorists were received, giving a response rate of 48%.

Table 1 – Characteristics of respondents.

| Description | Frequency | Ratio (%) | Description | Frequency | Ratio (%) |
|-------------|-----------|-----------|-----------------------------------|-----------|-----------|
| Gender | | | Occupation | | |
| Male | 35 | 66 | Management, administrative, sales | 20 | 38 |
| Female | 18 | 34 | Professional, technical | 16 | 30 |
| Age (years) | | | Student | 17 | 32 |
| 21–24 | 20 | 38 | Driving frequency (per week) | | |
| 25–40 | 31 | 58 | Up to 3 days | 21 | 40 |
| 41–55 | 2 | 4 | 4–7 days | 32 | 60 |

The majority of respondents were male, in the 25–40 age group. Most of them work as professionals, managers, executives, and technicians. Among the respondents, 60% drove four to seven days a week. Details of the respondents are given in Table 1.

The analysis of the PLS model is a two-step approach which first assesses the measurement model and then the conceptual model. Due to the lack of a global quality criterion, the criteria to evaluate reflective and formative constructs as well as the path model were based on the extant literature (cf. Ringle et al., 2012).

5.1. Measurement model

The measurement model used two reflective indicators for measuring the value-in-use construct: the evaluation of the overall road network performance and the evaluation of the agency's road work coordination. Indicator reliability determines which part of an indicator's variance can be explained by the construct, and loadings of indicators on the construct of more than 0.70 are regarded as acceptable in this regard (Götz et al., 2010). The loadings of the two indicators used in the research exceed this threshold (0.880 for

network performance evaluation and 0.727 for activity coordination evaluation).

Composite reliability is used to assess how well a construct is measured by its indicators, and values of more than 0.70 are considered to be reliable (Fornell and Larcker, 1981). With a value of 0.94 the composite reliability for the value-in-use construct is satisfactory.

Another criterion for assessing reflective measurement models is convergent validity by determining the average variance extracted (AVE), the average variance shared between a construct and its indicators (Hair et al., 2012a). An AVE value of more than 0.50 is considered sufficient (Chin, 1998; Götz et al., 2010), which is the case for the value-in-use construct (AVE = 0.88).

The measurement model also includes formative indicators for measuring road users' experiences with road maintenance and traffic management. Formative indicators are primarily evaluated on the basis of their weights (Hair et al., 2012b). The weight indicates how important the variable is for determining the associated construct, controlling for the effects of all other indicators of that construct. It shows the relative importance of an indicator to the construct. Another criterion is the statistical significance of the indicator weights, which can be

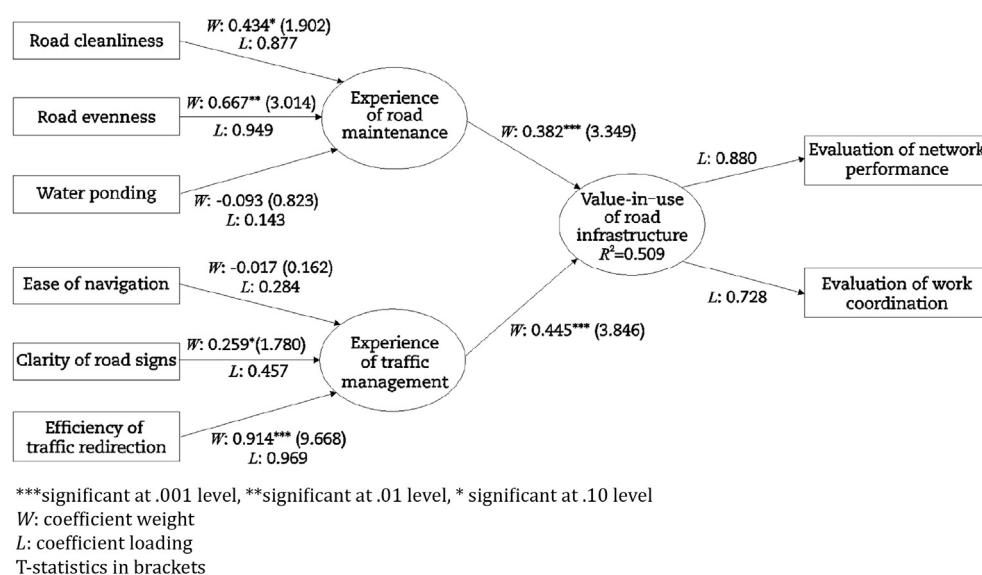


Fig. 2 – Results of the model analysis.

obtained by applying a bootstrapping procedure; the observed sample is seen as the population from which a large number of bootstrap samples are created (Henseler et al., 2009). The indicator weights and their significance are presented in Fig. 2.

The analysis reveals that road cleanliness (0.434) and road evenness (0.667) have a significant effect on the experience of road maintenance, with road evenness making the greater contribution. Both indicators also show high loadings (0.949 for road evenness and 0.877 for road cleanliness) which indicate their absolute importance for the maintenance experience. Water ponding does not influence the road maintenance experience. Its weight and loading are low and not significant compared to the other two indicators. That suggests that the road drainage system works effectively and motorists do not face any difficulties caused by water on the road. From a value-in-use perspective it also suggests that road evenness and road cleanliness are more prevalent for motorists while driving on the road. Both road conditions appear to be more directly linked with the service experience of motorists. Water ponds are temporary and localized incidents which motorists may encounter infrequently and, thus, hardly remember. An uneven road surface is the outcome of a deterioration process and will be noticed by motorists if they regularly drive on affected road sections. The same holds for litter along the road, which may accumulate after a while and becomes an eyesore. This may be the case for the majority of the respondents who use the road network 4–7 d per week (Table 1). More general and in line with Ettema et al. (2013), it can be argued that road users aggregate their recurrent experiences of road conditions and that their remembered experiences will influence their general perceptions of an agency's maintenance services. For the road agency, it seems important to know whether its maintenance standards lead to an accumulated positive experience of road users which confirm the actual experience of single rides. In this regard, approaches which directly measure user perception of ride quality and compare this perception with maintenance standards (c.f. Poister, 1997) can help in translating user experiences into road condition metrics.

Important and significant indicators for the experience of traffic management are the clarity of road signs (0.259) and the efficiency of traffic redirection (0.914). Ease of navigation does not play a role for the traffic management experience of motorists. Although the loading (0.2836) shows that the indicator possess some importance in a one-to-one relationship with the construct, it is still lower than the loading of the other two indicators (0.4574 for clarity of road signs and 0.9693 for efficiency of traffic redirection). A possible explanation is that most of the respondents are professionals who regularly use the road network (Table 1). They normally know the network and the way to their regular destinations. For these motorists, disruptions on and closures of their known and often used routes then become critical for the value-creation process, since they may be late for work or appointments. That also may explain the dominant influence of the efficiency of traffic redirections on the traffic management experience. Even if they know in advance that they have to make a detour,

the risk of being late remains due to additional traffic on the detour. If “the value of an object is related to what individuals want objects to be and do for them” (Grönross and Ravald, 2009), then in the Singapore context, the value of road infrastructure is related to the time-aspect (punctuality) in the business processes of motorists. This is also echoed by the findings of Ettema et al. (2013) who found a negative valuation of traveling by road users in the specific circumstances of road construction work.

5.2. Conceptual model

The results of the assessment of the conceptual model are shown in Fig. 2. The central criterion for the assessment of the structural model is the coefficient of determination R^2 , which is used to characterize the ability of the model to explain and predict the dependent variable (Ringle et al., 2012). The R^2 of 0.509 for value-in-use of road infrastructure as the dependent variable in our research is satisfactory. A large part of the variance can be explained by the experience of motorists with the agency's road maintenance and traffic management activities.

The analysis of the path coefficients revealed a positive influence of both variables, suggesting that the better the experience of motorists with the agency's activities, the higher the contribution of the road infrastructure to the value-creation process of motorists. Both path coefficients are significant after applying bootstrapping where the observed sample is seen as the population from which a large number of bootstrap samples are created (Henseler et al., 2009). This underlines the importance of both activities for road users who derive value from maintained and managed infrastructure (Burde, 2008; Moon et al., 2009). The contribution of traffic management experience (0.445) is slightly stronger than the road maintenance experience (0.382). This might be explained by the direct influence of traffic management activities on the service provision of road infrastructure. Inappropriate and ineffective traffic management can directly result in traffic jams and longer travel time, which are immediately noticed by motorists. This is clearly linked with the efficiency of traffic redirections as main influence on the traffic management experience. In addition, a traffic-intensive and complex network such as in Singapore is very prone to traffic disturbances, which increases the importance of traffic management for the value creation of road infrastructure.

Road maintenance work temporarily reduces the service provision of road infrastructure, and the extent of this loss in services will (partly) depend on the traffic redirection measures. Here, the road agency can get actively involved in the motorists' experiences with the traffic parameter of road infrastructure and can directly contribute to the motorists' value fulfillment (cf. Grönross and Ravald, 2009). On the other hand, the deterioration of infrastructure and litter pollution is continuous processes, and their effects on the service provision of road infrastructure will not be immediately noticeable. The service experience appears to be more cumulative, and we suggest that as soon as a certain deterioration and pollution level is reached, motorists will recognize the reduced value-in-use of

road infrastructure. Road maintenance activities then indirectly impact the value creation process of motorists by making value proposition through the condition of road infrastructure (cf. Sandström et al., 2008).

6. Conclusions

Road infrastructure is a vital resource for the economic and social activities of modern societies, and road agencies contribute to the value this resource can create for its users. By adopting a service-dominant logic perspective, this study investigated the importance of two main activity types of road agencies on the value-in-use of road infrastructure: road maintenance and traffic management. While the data for this research were collected among motorists in Singapore, the findings may be generalized to other infrastructure networks that share characteristics similar to Singapore in terms of traffic intensity, network layout, and management activities. Countries that have centralized bodies to maintain and manage national road infrastructure but also road infrastructure in densely populated urban regions and cities – and these include many European, American and Asian countries – may use the findings to critically reflect on their maintenance and traffic management activities and the extent to which they facilitate the value creation of road infrastructure.

Our study revealed that both activity types are important contributors to the value creation of road infrastructure with a slightly stronger contribution of traffic management activities. We suggest that particularly for traffic-intensive networks, road users' direct experiences of the outcomes of traffic management activities and the immediate effect of traffic parameters on the service provision of road infrastructure explain this higher importance. An implication for road agencies is that they should pay more attention to traffic management activities which allow them to directly engage with the value-creation process of road users. Since road maintenance indirectly impacts the value-creation process and road users experience a loss in service provision more through cumulative deteriorating conditions, agencies should try to determine the thresholds at which the value-in-use of road infrastructure is affected and recognized by road users. Here, a more direct dialog through focus groups, surveys and accompanied rides can reveal the accumulated and remembered experience of road users and the possible discrepancy with their actual and momentary experience when using a road. That appears to be important, since any maintenance intervention applied on a traffic-intensive network will have a high probability of inducing traffic disturbances. Road agencies need to find appropriate maintenance strategies which reduce and coordinate simultaneous maintenance interventions on the network to such an extent that traffic management activities are able to minimize any considerable loss of traffic flow.

The results of the research also point to road maintenance and traffic management activities a road agency should focus on in order to increase the value-in-use of road infrastructure. Important road maintenance activities include those which aim at road evenness and road cleanliness. Here, activities with the aim of improving road evenness will have a greater

influence on road users' experience of road maintenance. Important traffic management activities include traffic redirection and road signage, with traffic redirection having a significant influence on the experience of traffic management activities by road users. It should be noted that the outcomes of road maintenance and traffic management activities reflect the importance of activities as determined by the particular road agency. In other words, road agencies cannot only put emphasis on activities related to condition and traffic parameters included in this study, but could identify other activities which address additional parameters and contribute to the value-in-use of their road infrastructure network. In this regard, the study was limited to the condition and traffic parameters that were important from the perspective of the Singapore road agency. However, in terms of quality of roads, Singapore is ranked 6th ([The Global Competitiveness Report 2014–2015](#)), which proposes maintenance and traffic management activities of the Singapore road agency as benchmarks for other agencies.

The limitation of the research to the Singapore context and to the perspective of the Singapore road agency offers avenues for further research. First of all, future studies should further improve our understanding of the role of road infrastructure in the value-creation process of road users and the condition and traffic parameters that affect the service provision of a road. That may include a more detailed differentiation of road users, their characteristics and purposes of using road infrastructure networks. In addition, future studies could also fruitfully compare the effectiveness of road agencies in contributing to the value creation process of road users. An interesting question might be: to which extent does the importance of maintenance and traffic management activities differ between road networks with high and low traffic intensity? Such insights will help road agencies in transforming their business logic from a technical-oriented infrastructure supplier to a value-oriented service provider.

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