Determining a Threshold of the Damaged Road Which Categorized to Fail of Service In Accordance with Road User Satisfaction

Marsinta Simamora 1) And Jati Utomo Dwi Hatmoko 2)

[1]Civil Eng.Depart, Kupang State Polytechnic, East Nusa Tenggara, Indonesia.

[2]Civil Eng.Depart, Diponegoro University, Central Java, Indonesia.

Abstract

The non-toll national road (ntNR) management in Indonesia indicated that it is less optimal. One of the indicators is the increase of the road management budget which is not in line with the increase of the significant benefit. One of the alleged as a possible cause is no difference between the roads which severely damaged and failed, so it is difficult to apply laws and regulations that exist. This study aims to determine a threshold of damage road which failed of serviceability function in accordance with road user satisfaction. The research was conducted using a qualitative approach. Respondents' opinions against the service on the damaged road segments were measured using a Likert scale, which is adapted to service standards of ISO2631, while the value of damage was measured using the standard AASHTO 1993. The result showed the road that was failed of service was at a value CDV > 87.01 or PCI <12.99. By obtaining a threshold of the damaged road which failed of service, then, the road assessment system can be improved by adding the label "failed". As the implication of this study, the Law of Indonesian Republic No.18/1999 and the Government Regulation of Indonesian Republic No.29/2000 can be applied in the ntNR management system.

Keywords: *management, damage road, failure, serviceability, threshold, and road user*.

1. Introduction

The non-toll national road (ntNR) management in Indonesia indicated that it is less optimal. One of the indicators is the increase in the budget for road management is not in line with the increase of the significant benefit. Based on the data of Public Communication Center at the Department of PublicWorks in 2013, the cost per km of ntNR management in 2011and 2012 was IDR 725,304,900 and IDR 1,045,890,329, respectively. If we assumed that in general ntNRs have 2 lines and 1US$=IDR 9,500 (at the time ago), then ntNR management costs per km per lane in 2011 and 2012 was US$ = 38.174 and US$ = 55.047, respectively. Pavement condition index (PCI) before the treatment in 2011 and 2012 was 50.16 (medium category) and 50.13 (medium category), respectively. After the treatment, PCI value in 2011 and 2012 was 50.13 (medium category) and 52.67 (medium category), respectively.

The change of the the PCI after treatment on the road can be used as a indicator to confirm whether the benefits derived optimal or not (Khurshid et al., 2011; Dong and Huang, 2012; Fwa and Farhan, 2012). By using that concept, in 2011 the benefit gained almost nothing. That can be seen from the PCI after treatment was lower than before, where a decline in PCI was at 0.03. While in 2012, the benefit of treatment was at 2.54, there was an increase in the PCI but it was not optimal.

Jimenez and Mrawira (2009) mentioned that in order to increase the PCI from 60 to 80 in the class of hight raffic category performed minor maintenance actions at a cost of US$ 56,000 per km/lane. When compared to the cost of ntNR management on average per km/lane in 2012 which was almost equal to the cost of handling standard proposed by Jimenez and Mrawira (2009), should have obtained a minimum benefit value of 20 (80-60), but the fact showed that the benefit obtained only 2.54, so far from expectation which is 20.

The question is why the ntNR management is not optimal. One of the alleged as a possible cause is no difference between the roads which severely damaged and failed. At present, in the road evaluation system, the road condition is only grouping in 4 categories, namely: 1) good, 2) moderate, 3) light damage, and 4) severely damaged. This situation might have an impact on: 1) the possibility of errors on road handling (e.g. reconstruction should be done but in fact should not), 2) can never be assessed against the accountability of road damage, in accordance with law and regulation that were exist, because the Law of Indonesian Republic (LOIR) No.18/1999 and the

Government Regulation of Indonesian Republic (GROIR) No. 29/2000 state that only the buildings that "failed building" have the responsibility such as sunction. In fact, bad road may have performed below minimum standards, which are often depicted with terminal performance index (IPt) [Zhang et al., 2010]. Noon (2009) mentioned that performance under the minimum acceptance is categorized fail.

Indeed, the decline in road condition (deterioration) can not be avoided and inevitable (Hudson et al., 1987; Zhang et al., 2012). Pavement deterioration is influenced by three main factors, namely: 1) pavement design and materials (surface layer, base, sub base layers, and subgrade, 2) vehicles load (traffics), 3) environment, and 4) maintenance (Hong and Prozzi, 2010; Al-Mansour et al., 1994). Even Hudsonet al. (1987) mentioned that the failure may occure due to naturally of aging, where the structural capacity decreases to exceed a minimum threshold that resulted in the destruction of.

However, the damage of the road pavement should be accountable and should not go unpunished. Never again use the principle if it breaks do repair. Castro and Fernandes (2004) mentioned in getting more objective and accountable information needed investigations regarding to: i) what is going on, ii) where they are occurred,iii) how it happened, iv) who or what caused it, v) who is responsible for what happened, vi) what is the cost of repair or reinstatement, and vii) what compensation imposed on the parties concerned. In NntR management system, the principle of Castro and Fernandes (2004) is considered to be able tracing such as the cause, the parties concerned and what the impact of the NntR management which is less optimal.

Unfortunately, at this time, the existing evaluation system yet can be used to assess the accountability of road damage in accordance with the existing rules. That is caused due to the damaged roads are not mentioned as a problem in legal systems in Indonesia, especially by law of construction services. According to LOIR No.18/1999 and GROIR No.29/2000, that building can be sanctioned when the building can be categorized into building failure. Therefore, the accountability of heavely damaged road cannot be audited during the heavily damaged road cannot be categorized as part of building failure. For this reason, it is needed the effort to determine the characteristics of road damage as part of building failure.

The system thinking in formulating the characteristics of road damage as part of building failure is using the pavement performance approach as described in pavement design. According to Zhang et al. (2010), the road pavement performance is consisted of the structure and serviceability performance. Pavement service performance is a form of pavement services to users which is affected by the intensity of the holes, cracking and rutting, while the structure performance is the level of support to the traffic load (Mustafavi et al., 2013; Mariani et al., 2012). Whilst, Parket al. (2007) mentioned that the road is how the service can provide a sense of security and comfort for the rider at design speed.

By using the pavement performance approach is expected the assessment on the severely damaged road can fulfill the rules of a domain ontology for construction knowledge (DOCK). According to El-Diraby (2013), DOCK is a constructive and pragmatic claim to knowledge of construction. DOCK aims to provide a platform to build a form or level ontology; facilitating the construction of information system on existing fundamental ontology according domain. Based on the DOCK's principle (El-Deraby, 2013), the heavily damaged road will be evaluated regarding to: 1) the damaged road that failed of service and 2) the damage road that failed of structure, in accordance with the principles of pavement design (AASHTO, 1993). This study aims to determine a threshold of the damaged road that failed to serve using road users satisfaction.

The criterion used to failed of service is the performance which it is under of minimal acceptance (Noon, 2009). Simamora and Hatmoko (2013) revealed at least 33.3% experts agreed that riding unsafe and uncomfort were as boundaries of failed of service. Park et al (2007) mentioned that the road which is not safe and convenient used driving at the design speed that is categorized as functional failure. In the other hands, there are several indicators related to serviceability function, i.e: safety and comfort (Park et al., 2007; Regulation of the Public Works Minister of Indonesia Republic No.14/PRT/M/2010), and satisfaction (Regulation of the interior Minister of Indonesia Republic No. 6/2007). In the previous study, to explain satisfaction or ride comfort was used the intensity of vibration when driving (Yang et al., 2009; Falou et al., 2003;Uys and Els, 2007; Els, 2005; Cantisani and Loprencipe, 2010; Corriere and Vincenzo,2012).

2. Literatur Review

In this paper, several topics had been reviewed regarding to: 1) present serviceability index (PSI) according to AASHTO, 1993, 2) PSI value on service level, and 3) the relationship between service level (according to he road user satisfaction) and the level of damage road.

PSI according to AASHTO, 1993

Generally, the method of flexible pavement component analysis is using a nomogram flexible pavement design (AASHTO, 1993;Pt-T-01-2002-B). Before using the nomogram is usually determined:

1. Traffic estimates in future periods (W18), the accumulation of the load at the end of life design
2. Reliability (R)
3. Overall standard deviation (S0)
4. Resilent modulus effective subgrade
5. Design serviceability loss ($\Delta PSI = IP_0 - IP_t$)

Pavement thickness in these guidelines are based on the relative strength of each pavement layer by using Eq. 1, as follows :

$$SN = a1D1 + a2D2m2 + a3D3m3 \quad (1)$$

where: SN = structural number; a1, a2, a3 = coefficient of relative strength of pavement materials; D1, D2, D3 = thickness of each layer of pavement; m2, m3 = drainage coefficient; Number 1,2,3 respectively for the surface layer, base layer, and subbase layer.

Besides using a nomogram, SN can also be calculated using Eq.2 (AASHTO 1993; Zhang et al., 2010; Pavement interactive, 2008 dan Pt T-01-2002-B) as follows:

$$\mathrm{Log}W_{18} = Z_R * S_0 + 9{,}36 * \mathrm{Log}(SN+1) - 0{,}20 + \frac{\mathrm{Log}\left(\frac{\Delta PSI}{IP_0 - IP_f}\right)}{0{,}40 + \frac{1094}{(SN+1)^{5{,}19}}} + 2{,}32\mathrm{Log}M_R - 8{,}07 \quad (2)$$

where: W_{18}= estimated number of equivalent standard axle loads 18-kip; Z_R = normal standard deviation as a function of the confidence level (R), ie, assuming that all input parameters used are mean values (Sebayang et al., 2008); S_0= standard error of traffic prediction and performance; M_R= effective modulus of subgrade; $\Delta PSI = IP_0 - IP_t$ = loss of service = Difference between the initial design serviceability index (IP_0) and terminal design serviceability index (IP_t) [Pt T-01-2002-B]; IP_f= failure serviceability index (Pt T-01-2002-B) = 1.5. Usually, IP_0 = 4.2; IPt = 2 (Pt T-01-2002-B); ΔPSI = 4.2 - 2 = 2.2

PSI value paired to level of service

In this section the intent of the PSI value is presented as a service received by road users.

PSI values and services

Santos and Ferreira (2012) described a set of value of IPo (PSIo) and IPt (PSIt) in accordance with roads classes as showed at Table 1.

Table 1. A set of value of PSIo and PSIt

Road class	PSI_0	PSI_t
Highways	4.2-5.5	2.5-3.0
National roads (jalan	4.2-4.5	2.0
Municipal roads	4.2-4.5	1.5

Source: AASHTO 1993 (Santos and Ferreira, 2012)

Generally, the cognitive mean of the IP can be seen in Table 2, in which according to Hudson et al. (1987) that the IP is equal to the PSI.

Table 2. Relation between Serviceability and Pavement (surface) index (PI)

No.	Pavement (surface) index (PI)	Serviceability
1	4 – 5	Very good
2	3 – 4	Good
3	2 – 3	Moderate
4	1 – 2	Bad
5	0 – 1	Very bad

Source : Sukirman (1992) and Pt-T-01-2002-B

Serviceability indicators

Regulation of interior minister of Indonesia Republic No. 6/2007 state that the service indicator is customer satisfaction. In terms of the road user, the customers were road users. While, Zeithaml et al. (1990) stated that customer satisfaction can be measured by several variables as in Table 3.

Corresponding between the PSI values and level of serviceability

Several previous studies have performed to measure the road service using objective and subjective approach as shown in Table 4.

Determination of damage road value

Suswandi et al. (2008) said that PCI can be used to evaluate the road condition in supporting of decision making. Mentioned that the severity level is the damage level of each type of damage that it is classified into low severity level (L), medium severity level (M) and high severity level (H). PCI is calculated by the following terms: 1) determining density of damaged, 2) determining the deduct value (DV), 3) determining the total of deduct value (TDV), and 4) determining the corrected deduct value (CDV).

$$Density = \frac{Ad}{As} \, x \, 100\% \quad (3)$$

where:Ad = the total of damage for each unit of measurement segment (m2); As = area of unit of measurement segment (m2).

Table 3. Dependent and explanatory variables of customer satisfaction

Dependent variable	Indicator	Explanatory variable	Variable description in accordance with road user satisfaction
Serviceability	Customer satisfaction	Tangiable	vibration intensity
		Reliability	safety and comfort
		Responsive	safety and comfort
		Assurance	speed
		empathy	safety and comfort
Source: Zeithaml et al.(1990)			(extrapolated from the service on the road)

Table 4. PSI (IP) value paired with objective/subjective measures

No	Performance Index (PI)	Serviceability	Objective value (ISO2631-m/s2)	Subjective comment/acceptability
1	4 – 5	Very good	<0.315	Not uncomfortable
2	3 – 4	Good	0.315-0.63	A little uncomfortable
3	2 – 3	Moderate	0.5-1.0	Fairly uncomfortable
4	1 – 2	Bad	0.8-1.6	Uncomfortable
5	0 – 1	Very bad	1.25-2.5	Very uncomfortable
ref	Sukirman (1992) and Pt-T-01-2002-B		Yang et al. (2009); Uys and Els. (2007); Els (2005); Cantisani and Loprencipe (2010)	

DV is value reduction for each type of damage obtained from the relationship between the density curve and deduct value. Deduct value is also distinguished by degree of damage for each damage type. TDV is the total value of individual deduct value for each type of damage and the level of the damage to a unit of study. CDV obtained from the relationship between the curve of the TDV and CDV values with selecting of curve and corresponding to the number of individual deduct value that have a value greater than 2. If the value of CDV is known, then the PCI value for each unit can be determined by the Eq.4:

$$\mathrm{PCI}_{(s)} = 100 - CDV \quad (4)$$

where: PCI(s) = pavement condition index for each segment, CDV = corrected deduct value for each segment. For over all value of PCI used Eq.5.

$$\mathrm{PCI} = \frac{\sum \mathrm{PCI}\,(s)}{\mathrm{N}} \quad (5)$$

Where: PCI = value overall PCI; PCI (s) = Value PCI for each segment; N = Number of segments.

Relation between Level of Service and Road Surface Damage

According to Hudson et al. (1987), the relation between the PSI and the value of road conditions is shown by Eq.6.

$$\mathrm{PSI} = \mathrm{C} + (\mathrm{A}_1\mathrm{R}_1 + \cdots) + (\mathrm{B}_1\mathrm{D}_1 + \mathrm{B}_2\mathrm{D}_2 + \cdots) \pm \mathrm{e} \quad (6)$$

where; C = coefficient (5.03 to 5.41 for flexible pavement and rigid pavement); A1 = coefficient (-1.91 to -1.80 for flexible pavement and rigid pavement); R1 = roughness = log (1 + SV), SV = average slope variation obtained with tools CHLOE profilometer B1 = coefficient (-1.38 to 0 for flexible pavement and rigid pavement); D1 = function rutting (RD), RD = rutting depth; B2 = coefficient (-0.01 to -0.09 for flexible pavement and rigid pavement; D2 = function deterioration (C + P); C + P = amount of cracking and patching obtained with procedures AASHO (American Association of State Highway Officials) Road Test; e = error

Higher User Attitude Toward Pavement Functionality		PCI	PSI			Explanation
INCREASINGLY FAVOURABLE	↑	100	5	Excellent	Satisfaction	Satisfactory condition and Vehicle operating cost
		80	4	Good		
NEUTRAL		60	3	Fair		
	↓				Candidate	User cost sharply Rising Complaints starting about condition
		40	2	Poor		
INCREASINGLY UNFAVOURABLE					Essential	User costr excessive, frequent complaint
		20	1	Very Poor		Extreme discomfort Traffic slowdowns Extremely high user costs
		0	0			

Figure 1. Significance of PCI and PSI on pavement evaluation (Hudson et al., 1987)

In Fig. 1, we can see that there is a relation between the PCI and PSI in which PCI describes the physical condition of the road and PSI describes the service level.

3. Research Method

The study was conducted through two main terms, ie: 1) determining the damage value (use Eq.3,4, and 5) used evaluating road's level of service, 2) determining the level of service on each road segment (there are 4 segments) with different levels of damage. Term of analyses: 1) testing the validity and reliability of the research instrument, 2) determining the relationship between the damaged road and the composite service, 3) determining the damaged road value that was failed of service.

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Research operational variables

The operational variables in this study can be seen in Table 5. The basic relations between the variables could be described as follows:

a) Yi = f(Yi1, Yi2, Yi3); Yi, Yi1, Yi2, Yi3 in scale 1-5
b) CDV = Xi = f (Xi1, Xi2, Xi3); density of Xi1, Xi2, Xi3 in (0-100%)
c) Yi = f (Xi)

4. Results and Discussion

Validity and Reliability of research instrument

To determine a accurate and stable research instrument were conducted testing against the validity and reliability. The tests were performed for a series of research instruments using 41 respondents who were picked by random sampling. A number of respondent in the trial,suggested were about 20-30 people (Muhidin and Abdurahman, 2007).

Table 5. A series of research operational variables

Dimension	Operational variable		Notation	Measurement standards
Damaged road	Dep. Variable	CDV	Xi	AASHTO, 1993
	Ind. Variables	PH	Xi1	
		CRACK	Xi2	
		RUT	Xi3	
Serviceability	Dep. Variable	Satisfaction	Yi	AASHTO, 1993; ISO 2631; Zenithaml et al. (1990)
	Ind. Variables	Intensity of vibration (tangiable)	Yi1	
		Safety and comfort (reliability/assurance)	Yi2	
		Speed (assurance)	Yi3	

<u>Instrument validity test</u>

In Table 6, it can be seen the results of the validity test. The validity of the instrument was tested using a student-t by comparing t count and t table. The results shown that t count for Yi, Yi1 and Yi2 are 10 385; 11,124, and 6.516, respectively. Those were greater than t table = 2.022, while t count for Yi3 is 1,681 that is lower than t table. When t count > t table, the instrument is valid and if t count < t table that is invalid. Based those requirement, Yi (service/satisfaction), Yi1 (vibration), and Yi2 (safety and comfort) are the valid instrument and Yi3 (speed) is the invalid instrument.

<u>Instrument reliability test</u>

Reliability of a valid instrument can be measured using Cronbach Alpha (r) as can be seen in Table 7. Accordance with the results of validity and reliability test can be mentioned that the variables which are valid and reliable those are:

1. Yi (satisfactory)
2. Yi1 (intensity vibration)
3. Yi2 (safety and comforts)

Table 6. The instrument validity test

Variable	Validity test method								
	Factor analysis method			Pearson Analysis method					
	KMO MSA	Require	Remark	r_{count}	r_{tabel}	t_{count}	t_{table}	Require	Remark
Yi	0.583	KMO > 0.50	valid	0.883	0.308	10.385	2.022	$t_{hitung}>t_{tabel}$	Valid
Yi1	0.594		Valid	0.910	0.308	11.124	2.022		Valid
Yi2	0.837		Valid	0.869	0.308	6.516	2.022		Valid
Yi3	0.165		invalid	0.243	0.308	1.681	2.022		invalid

Table 7. The Instrument reliability test

Variable	Cronbach Alpha (r) count	r_{table}	require	Remark	t-test			
					t_{count}	t_{table}	require	Remark
Yi	0.649	0.308	$r_{count}>r_{table}$	Reliable	5.327	2.022	$t_{hitung}>t_{tabel}$	Reliable
Yi1	0.703	0.308		Reliable	6.173	2.022		Reliable
Yi2	0.877	0.308		Reliable	11.398	2.022		Reliable

Table 8. Data measurement of road damage and serviceability functions

Segment-i	Xi	CDV	PCIs = 100-CDV	Respondent (N-people)	Component of the road service		
					Yi	Yi1	Yi2
1	X1	61,55	38.45	95	2.94	3.66	2.83
2	X2	70,82	29.18	102	2.38	3.09	2.47
3	X3	80,17	19.83	110	2.02	2.45	1.87
4	X4	90,34	9.66	101	1.72	1.73	1.69

Table 9. Mean value of Yi, Yi1,and Yi2 in accordance with CDV

CDV-61.55% Segmen-1 (i=1)			CDV-70.82 % Segmen-2 (i=2)			CDV-80.17 % Segmen-3 (i=3)			CDV-90.34 % Segmen-4 (i=4)		
Mean		Katego ry	Mean		Kategory	Mean		Katego ry	Mean		Kategory
Y1	2.94	quite satisfying	Y2	2.38	unsatisfying	Y3	2.02	unsatisfying	Y4	1.72	Very unsatisfaying
Y11	3.66	A little vibration	Y21	3.09	Real vibration	Y31	2.45	severe vibration	Y41	1.73	vibration very severe
Y12	2.83	quite safe and comfort	Y22	2.47	unsafe and uncomfort	Y32	1.87	unsafe and uncomfort	Y42	1.60	Very extremely unsafe and uncomfor

Yi= serviceability for segmen-i; Yi1= vibration intencity for segmen-i; Yi2= safe and comfort for segmen-i.

The research data

The research data presented in Table 8. Additionally, from the data in Table 8, level of service are labeled on each road segment in accordance with the level of damage as can be seen in Table 9.

Relations between CDV and composite services (Yci)

The relations between the CDV and the composite services (Yci) can be constructed based on the average value of the service. The average value of the composite service is:

$$Yci = \frac{(Yi+Yi1+Yi2)}{3} \quad (10)$$

Table 10. The composite service (Yci)

Segmen-i	CDV	Yi	Yi1	Yi2	Yci
1	61.55	2.94	3.66	2.83	3.14
2	70.82	2.38	3.09	2.47	2.65
3	80.17	2.02	2.45	1.87	2.12
4	90.34	1.72	1.73	1.60	1.69

By using Eq.10, the composite service (Yci) can be determined and the results are as in Tab.10. Additionally, using the SPSS 17th ver., the best relation between the composite service and the CDV was found in exponential function form as following:

$$Yci = Ln\,(12.139) - 0.022CDVi$$

or

$$Y_{ci} = 12.139.\,e^{-0.022\,CDVi} \quad (11)$$

where: R^2adj = function determination after adjustment = 0.996, Yci = the composite service on the i-th segment, CDVi = the corrected deduct value on the i-th segment.

CDV value that failed of service

The final part of this study is to determine the CDV value which was failed of service. Based on the failed of service parameters, e.i: 1) Very unsatisfying, 2) Vibration very severe, and 3) Very extemely unsafe and uncomfortable and using Eq.11, the CDV value which was failed of service is determined on the interval scale of service $1 \leq Yci \leq 1.79$, as can be seen in Table 11. At the Table 11, it can be seen that serviceability is failed when Yci =1.79, and at the same time the CDV is at 87.01. Based on data from Table11, the relations between CDV and Yci can be seen in Fig.6.

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5. Conclusions and Recommendations

As the purpose of this research intended is determining a threshold of damage road that it was failed of service,then:

1. The parameters of failed of servive are:
   a) Very unsatisfying
   b) Vibration very severe
   c) Very extemely unsafe and uncomfortable
2. The limit of the dameged road that was failed of service is CDV > 87.01 or PCI < 12.99.

With the failed threshold on the damaged road serviceability, then the badly damaged road are not always further categorized on the heavily damaged but may be held to account under the LOIR No. 18/1999, using the clause"building failure". However, to ensure a failed of service road can be categorized as part of building failure, it is necessary to test the ability of road structure whether it's a failure or not. So that, the damaged road can be categorized as part building failure when it is fail service and structure.

6. Future Work

To determine failed structurally on damaged road is in progress at author's research.

Table 11. CDVvalue that failed of service

CDV	constant (c)	(-0.022CDV)	e^(-0.022CDV)	Yci = c.e^(-0.022CDV)
60.00	12.139	(1.32)	0.267135302	3.2428
70.00	12.139	(1.54)	0.214381101	2.6024
81.97	12.139	(1.80)	0.164765834	2.0001
81.97	12.139	(1.80)	0.164747711	1.9999
86.00	12.139	(1.89)	0.150769967	1.8302
87.00	12.139	(1.91)	0.147489248	1.7904
87.01	12.139	(1.91)	0.147456804	1.7900
87.20	12.139	(1.92)	0.146841721	1.7825
90.00	12.139	(1.98)	0.138069237	1.6760
95.00	12.139	(2.09)	0.123687136	1.5014
96.00	12.139	(2.11)	0.120995733	1.4688
99.00	12.139	(2.18)	0.11326784	1.3750
100.00	12.139	(2.20)	0.110803158	1.3450

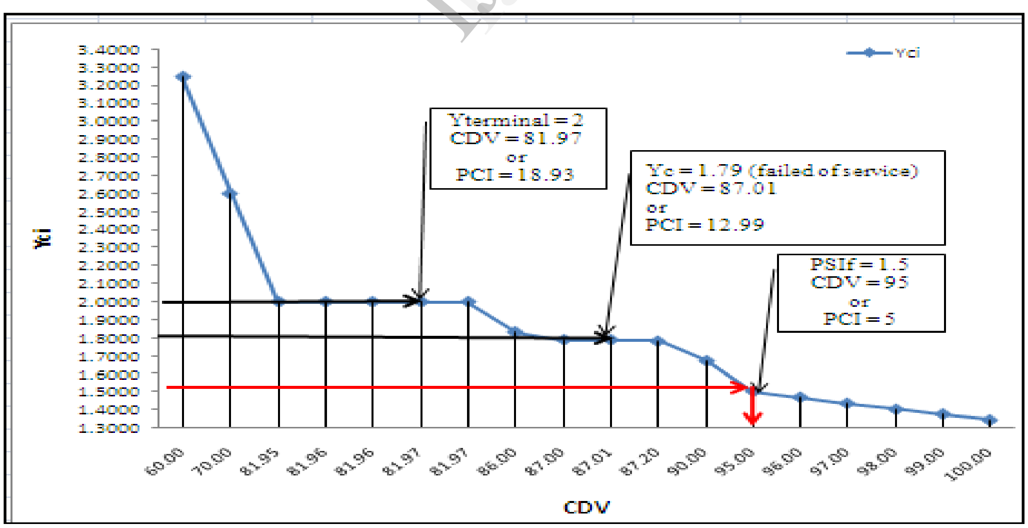

Figure 6. CDV vs Yci

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