Pavement Distress Evaluation Using Pavement Condition Index around Agora Market, Barangay Lapasan, Cagayan de Oro City

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Abstract: A vital necessity to economic progress of any city is its roads with better pavement condition. Pavement designs must enhance skidding resistance between vehicle tires and pavement surface, thus, increases safety, which in turn reduces travel time and delay. However, due to external factors such as vehicular loading, density, temperature, design, sub grade and construction quality, the existence of pavement deterioration, called distress, cannot be prevented. The calculation of Pavement Condition Index (PCI) was used to assess the three circumferential streets around Agora Market: Valenzuela Street, Gaabucayan Street and Mambato Street, to determine the pavement condition as to severity of pavement distresses. Modified financial benefit-cost analysis was also used to determine whether or not the cost of benefit will exceed the construction cost. The results show that the pavement distresses along the circumferential road in Agora Market needs reconstruction considering that the overall rating scale revealed "failed" condition.

Keywords: PCI, density, distress, modified benefit-cost analysis, pavement condition

1. INTRODUCTION

Road pavement is a durable surface material laid down on an area intended to sustain vehicular or foot traffic such as a road or walkway. There are two classifications of pavement: (1) Portland Cement Concrete Pavement (PCCP) which is composed of a Portland cement concrete and when specified, reinforcing steel and various joint materials; and the (2) Asphalt Concrete Pavement (ACP) which is composed of black cementing agent known as the asphalt. Roads connect one city to the other, augment the country's economy, provide ease of access to work place, facilitates public service, and gives benefit to vehicle users through lower cost of operation and maintenance. The purpose of a good road pavement is to effectively spread the load from vehicles over a wider area of the existing natural surface, so that the strength of the natural ground will be sufficient to carry the reduced loading without causing any type of failure on the pavement (C.J. Summers, 2000).

However, road pavement quality is affected by various factors such as traffic volume, vehicle loading, thermal factor on the pavement, natural calamity, seasonal variation, pavement design, and human factor (Biscocho, 2013), leaving distress (an exterior indicator of pavement deterioration) to public roads, which will then take effect to the country's economy, safety, and eventually, to the livelihood of the people. In terms of mobility, previous studies have focused on the link between weather variables such as precipitation intensity and wind speed; and traffic characteristics such as speed, capacity, and volume (Datla and Sharma, 2008). However, maintaining base pavement enhances skidding resistance between vehicle tires and pavement surface and therefore increases safety and roadway capacity, which in turn reduces travel time and delay (Shahdah, 2009). As to Agora Market, though there were no reported cases of accidents due to the condition of the pavements, the flow or movement of vehicles is mostly affected. When a pavement is subjected to severe distress, a vehicle slows down which may cause queuing of vehicles and may result to traffic delay, depending on the vehicular volume present in an area.

Distresses are classified according to the type of pavement. For ACP, common distress includes fatigue cracking, longitudinal and transverse cracking, patching, potholes, raveling, and etc (Pavement Surface Condition Field Rating Manual for Asphalt Pavements, 2005). On the other hand, distresses present on PCCP are shattered slab, longitudinal and transverse cracking, spalling, pothole, faulting, and etc. (South Dakota Department of Transportation, 2009).

Early this year, tropical depression, *Agaton*, hit Mindanao leaving 56 fatalities, more than one million people affected and over 2,000 houses damaged according to the National Disaster Risk Reduction and Management Council (2014). Nine (9) roads and two (2) bridges were reported to be impassable in Cagayan de Oro City. Hundreds of residents have been forced to evacuate due to visible cracks in their houses' walls and floors, the tropical storm left a mark of visible cracks on road pavement along Barangay Lapasan, Cagayan de Oro City (Balsa Mindanao, 2014). Brgy. Lapasan, specifically Agora Market, is composed of PCCP with visible and a number of severe distresses all over the pavement. Existing distresses within the area includes patching, block cracking, potholes, raveling, edge cracking, fatigue cracking, and transverse and longitudinal cracking. These distresses must be repaired or reconstructed depending on its severity. In some cases, some sections are lightly distressed but most of them are severe. Damaged pavements are said to increase vehicle-operating costs and may result to consequent loss of economic and social development opportunities (Harvey, 2012), therefore immediate action must be considered. If road defects are repaired promptly, the cost is usually modest, but if neglected, the entire road section may fail completely. As a result, larger funds are needed since repair costs are said to be six times the maintenance cost (South African Nation Road Agency Ltd., 2004).

Due to this arising issue, the researchers wanted to evaluate the distresses of the road in Agora Market, Barangay Lapasan using Pavement Condition Index (PCI), a numerical value that describes the pavement condition. This study assess traffic volume and locate the pavement distress, to determine the index of each road sections. The evaluation outcome will then be interpreted through pavement condition rating, a scale that quantifies pavement's overall performance (ASTM D 6433-11, 2012) along Agora Road, considering the factors such as: (1) the current traffic and pavement condition of Agora, (2) the sufficiency of the pavement along Agora regarding its present volume of traffic; and (3) the proficiency of its present pavement condition to accommodate the future volume. It specifically provides comparison to considerable solutions through modified benefit-cost analysis.

2. REVIEW OF RELATED STUDIES

2.1 Pavement, Pavement Type, and Pavement Condition

A pavement is a durable surface material laid down on an area intended to sustain vehicular or foot traffic. Its design must be thick enough to structurally carry all expected loads for a period of time, must be properly compacted to develop its full strength, and prevent water penetration into the pavement and its base (Blades and Kearney, 2004). There are two classifications of pavement: (1) Portland Cement Concrete Pavement (PCCP) which is composed of Portland cement, aggregates, water, and when specified, reinforcing steel and various joint materials; and (2) Asphalt Concrete Pavement (ACP) which consists mainly of a black cementing agent, known as asphalt. Both types of pavements are subjected to challenging environments and loads over their lifetime therefore they must be strong, durable, yet cost effective and workable (Industrial Resources Council, 2014).

2.2 Local Literature

To minimize and reduce the issues regarding pavement distresses, Road Condition Assessment Manual Philippine Version No. 7 (ROCOND, 2006), together with the BantayLansangan (2008) were used by the Department of Public Works and Highways (DPWH).These manuals aim to provide an overview on essential information on road construction and maintenance as well as processes of conducting road-monitoring activities. Another method is through manual surveying on the road network (Gavilan, et.al., 2011). Two line scan cameras are equipped in a vehicle and laser illumination are used to store images to analyze the identity of the road crack. The images are processed to identify dark linear features (cracks) in the road pavement, coming up with a histogram analysis. A seed-based approach is proposed to deal with the road crack detection. This provides an accurate and precise measurement in assessing road distress. (Gavilan, et.al., 2011).

The data collected through assessments and manual surveys will be processed using Pavement Condition Index (PCI). It determines the level of severity of each distress and provides numerical rating of pavement condition that ranges from 0 to 100 where 0 as the worst possible condition and 100 as the best (ASTM D 6433-11, 2012). This index will also be helpful in identifying immediate maintenance and rehabilitation needs, develops a network preventive maintenance strategy, provides road maintenance budgets and it evaluates pavement materials and designs (Ogra’s Milestones, 2009). PCI must be conducted annually to evaluate changes in road condition.

2.3 Foreign Literature

2.3.1 Pavement management system

Maintenance in road pavement condition is needed. Pavement Management System (PMS), a decision-making tool (PMS Ltd., 2011) used to assist or aid pavement management decisions. It helps assist in finding cost-effective strategies for providing, evaluating, and maintaining pavements in a serviceable condition (Oregon Department of Transportation, 2011). PMS helps determine cost-effective repair alternatives. Thus, one of the numerous ways in cost-effective road maintenance is through modified benefit-cost analysis. It will be done to evaluate whether repairing or reconstructing a distressed pavement is more beneficial in terms of finance and efficiency. The analysis is set to compare two kinds of repair: to estimate the cost of an overall reconstruction of a section or the cost of an immediate repair; or even a “do-nothing” scenario. The modified benefit-cost analysis provides an indicator of benefits based on the available information, which will be converted into monetary terms.

2.3.2 Cause of pavement distress

The Pavement Cracking: A Failure Indicator of Your Roads (2012) introduced one of the major reasons why road deterioration occurs: fatigue due to pavement deflection. This fatigue refers to the excessive load that is distributed from the vehicle to the pavement. The load is directly proportional to the bending of the pavement; the greater the loading, the greater the bending, thus results to road failure. Also, it enumerates the different types of cracks or pavement failure and the type of repairs that must be applied since it is dependent on the extent and severity of the failure area. Also, each severity levels have its own definition of Low, Medium, and High Severity Cracking on every type of road failure.

Road deterioration is one of the main problems in transportation, and due to many factors, pavement distress occurs. Pavement cracks are present due to fatigue or the excessive loads that are distributed on the pavement; another cause is due to the base failure. Cracks have two classifications to identify its severity and extent. Cracks having a width of greater that 6mm may result in a rough riding surface and deterioration of the pavement, while hairline or narrow cracks usually having a width, of approximately 3mm, will not adversely affect the performance of the pavement (Adaska and Luhr, 2004). It also enumerates the several factors that cause cracks. One is the soil type which explains that fine-grained soils have greater shrinkage than granular soils. Another factor is the compaction. The base layer of the pavement must be compacted properly to avoid water from entering the mixture. Proper compaction reduces voids that may cause loss of aggregate interlock at the crack, layer separation and localized deterioration of the pavement along the crack. Another factor that causes cracks is the curing of pavement and the cement content. Some pavements aren't totally cured but vehicles are already permitted to use the pavement which then affects its life span since prolonged curing results in narrow crack widths and spacing. Cement content must also be sufficient in concrete mixture for pavements. The increase content of cement decreases total shrinkage, but having an excess amount of it can also result to cracks since it causes higher rigidity and excessive strength.

Also, pavements are subjected to vehicular loading and are known as one of the main factors why distresses exist. The larger the vehicle, the greater load the pavement needs to carry, thus, increasing the level of severity present on the pavement. According to the study from the proceedings of the Eastern Asia Society for Transportation Studies, results of damage factor analysis vary on which class of freight vehicles the pavements are subjected to. The damage factor increases as the class of freight vehicles increases. These freight vehicles are categorized according to class: class 6A for 2-axle-medium truck; class 6B for 2-axle-heavy truck; and class 7A for 3-axle trucks (Wahyudi, et.al., 2013).

Some factors causing pavement damage also include tire pressure aside from the environmental and classification of axle of the truck. Overloading is very often assumed as the factor that affects the level of severity of the distresses present on the pavement. The road condition is directly proportional or is dependent with the factors affecting the pavement. The higher the traffic volume and axle load, the higher the level of road damage it will be. Similarly, the higher the tire pressure, the higher the stress on surface layer of the pavement; which then contributes to the condition of the pavement.

3. METHODOLOGY

To be able to meet the researchers' objectives, a systematic approach must be *followed*. The researchers collected two types of data: the primary and the secondary. The collected primary data are the dimensions of pavement and distress, pavement type and condition, the type of distress and location. The secondary data are the satellite images from Google Earth (2014), Pavement Condition Index (PCI), Rating Scale (ASTM D 6433-11, 2012), weighted factor (MnDOT, 2011) and the traffic growth rate from the Department of Public Works and Highways (2008).

The gathered data will then be processed by calculating the Pavement Condition Index (PCI); a vital tool in determining and evaluating the severity of cracks with its corresponding scale and color per level, having dark grey color as failed (0%) and dark green color as a good pavement (100%). The PCI will then be calculated by the summation of the product of the weighted factor and the percentage density; wherein the weighted factor varies depending on the type and severity of the distress. Distresses with higher weighted factors have greater negative impact in the pavement condition (Almanzor, et.al., 2011). On the other hand, the percentage density is acquired by dividing the total area of the distress by the area of segment pavement (MnDOT, 2011). Since the level of severity per distress is identified through PCI, it will then be useful in constructing a Straight Line Diagram (SLD). This diagram displays the graphical presentation of the physical roadway characteristics of the selected area in Agora.

Modified financial benefit-cost analysis will be done to access whether repairing or reconstructing a distressed pavement is more beneficial in terms of finance and efficiency. The CBA is set to compare two kinds of repair: to estimate the cost of an overall reconstruction of a section or the cost of an immediate repair of a section; or even a “do-nothing” scenario. The CBA provides an indicator of benefits based on the available information, which will be converted to monetary terms.

Finally would be the recommendation of the study for Local Government Units (LGUs). This includes the design of pavement that will alleviate the existence of pavement distress. The obtained results of the evaluation will then be the basis of discussion for distressed pavement will undergo repair or reconstruction. If the range of pavement’s rating falls under level: Satisfactory to Good (75%-100%), repair or reconstruction is no longer needed or will be the “Do-Nothing” case. If it falls under the range: Fair to Poor (55%-70%), the pavement section will undergo repair. But if it falls under the category: Very Poor to Failed (0%-55%), the pavement needs to be reconstructed.

3.1 Primary Data Gathering

The primary data that were needed are the dimensions of the pavement and the distress, pavement type and condition, and the type of distress and its location. On-site survey inspection and manual measurement was done to determine the dimensions of the pavement and its existing distresses. The inspection of the pavement condition was necessary so as to determine the pavement type, the condition of the surface and the type of distress present on the pavement with respect to the level of severity. Location and of the distresses were also acquired by on-site inspection. These data were significant in the calculation of the Pavement Condition Index (PCI).

The determination of the severity of the existing pavement distress was dependent on the types and condition of the pavement. There were existing Surface Condition Matrix for Visual Monitoring which became a guideline of the surface condition corresponding to the surface type of the pavement. This guideline was published by Bantay Lansangan in order to have a basis of the determination of cracks and possible cause of failure.

3.2 Secondary Data Gathering

The secondary data includes the satellite image from Google Earth (2014), Pavement Condition Index (PCI), rating scale (ASTM D6433-11, 2011), weighted factor from Minnesota Department of Transportation (MnDOT, 2011) incorporated with the deduct values of ASTM D6433-11 (2011). The researchers were also in-need of the traffic growth rate from the Department of Public Works and Highways (DPWH, 2013). For the location of the streets in Agora Market, the researchers used a satellite image from Google Earth, prior to its pavement length. Also, the determination of the index is dependent on the weighted factors on both Asphalt Concrete Pavement (ACP) and Portland Cement Concrete Pavement (PCCP) so the researchers were able to acquire the data from the Minnesota Department of Transportation (2011).

$$\text{PCI} = \Sigma \text{ (Weighted Factor x Percent Density)} \quad (1)$$

where,

$$\text{\% Density} = \frac{\Sigma \text{ (Area of Pavement with Uniform Severity Level)}}{TotalAreaofPavementperStreet} x\ 100 \quad (2)$$

After determining the numerical value of the severity of pavement distress through PCI, the researchers were provided by the ASTM D6433-11 (2011) with the corresponding rating scale and suggested colors per level of distress of the affected pavement shown in Table 1. As to the Annual Average Daily Traffic (AADT), the researchers were given the data needed since it is one of the factors that can cause or trigger the pavement distress.

3.3 Method of Analysis

The method of data analysis incorporated in the study is the determination of the severity of road failure to evaluate the three circumferential roads in Agora Market through Pavement Condition Index (PCI). The numerical value obtained from the index was interpreted by the rating scale presented in a straight line diagram with different color intensities with corresponding qualitative meanings.

The results of the whole data processing were made as basis of the modified benefit-cost analysis whether the distressed pavement will undergo repair or reconstruction enumerating the disadvantages (the cost of the choice) and the advantages (cost of the alternative choice). After which, a ratio of the benefit-cost analysis was determined. This process was repeated for the alternative choice. Lastly, the ratio will be compared and the greater ratio was recommended as to the solution of the pavement with the existing distress.

3.4 Study Area

The circumferential streets around Agora Market which includes the streets of Valenzuela, Gaabucayan, and Mambato are Portland Cement Concrete Pavement (PCCP) and has four (4) lanes. Valenzuela Street is along the North-East (NE) direction, Gaabucayan along the North-West (NW), while Mambato Street is the access roads to both Valenzuela and Gaabucayan streets. It has a total road length of 1,609.39 meters. The Valenzuela Street has a length of 517.09 meters, Mambato with 346.89 meters and Gaabucayan, with 745.41 meters. The width of the streets, which were measured from curb to curb, are as follows: (a) Valenzuela with 17.3 meters; (b) Gaabucayan 12.74 meters; and (c) Mambato with 11 meters. The road is in PCCP. However, some portions with removed island were covered or patched with Asphalt Concrete Pavement (ACP).

Figure 1. Agora Market, Barangay Lapasan

Via ocular inspection, the researchers found that the road around Agora Market, namely, Valenzuela Street, Gaabucayan Street, and Mambato Street; were subjected to repeated traffic loading caused by Public Utility Vehicles (PUVs), Public Utility Jeepney (PUJs) cargo trucks, and other types of vehicles that travel back and forth the highway contributed to the severity of existing distress on the pavement. It was due to these observations that the researchers chose the Agora Market as the area of the study.

4. RESULTS AND DISCUSSION

4.1 Traffic Condition and Current Pavement Condition of Agora

The researchers were able to acquire the 2013 Annual Average Daily Traffic (AADT) of Cagayan de Oro to Port Road (CDO-Port), from the Department of Public Works and Highways (DPWH). This had been the basis of the researchers' AADT because most vehicle classifications that access the CDO-Port Rd are most likely the vehicles that enter Agora, according to Engr. Galez of City Engineer's Office – Cagayan de Oro (CEO-CDO). From the data acquired, the passenger car has the highest volume of AADT for CY 2013 with three thousand nine hundred seventy three (3,973) vehicles per day (veh/day); followed by motor-tricycle with three thousand four hundred sixty seven (3,467) veh/day; passenger utility with two thousand six hundred forty five (2,645) veh/day; rigid truck with a total of nine hundred sixty (960)veh/day; the semi-trailer truck (1-1), goods uitility, large bus, semi-trailer truck (1-2), and small buses having one hundred ninety five (195), one hundred forty one (141), one hundred ten (110), ninety three (93) veh/day, and seventy two (72) veh/day respectively.

Pavements around Agora Market are subjected into approximately one thousand six hundred (1,600) heavy trucks and large vehicles, with an additional of approximately ten thousand (10,000) light to medium vehicles that access the area per day. This implies that the

Agora Market is susceptible to pavement distresses due to the vehicle weights the pavements have to resist.

On the three circumferential streets in the research locale, the common Portland Cement Concrete Pavement (PCCP) distresses that were visible are patching, block cracking, pothole, raveling, edge cracking, longitudinal and transverse cracking, fatigue cracking, alligator cracking, and rutting. From the results, it showed that the "failed" condition dominates the three streets, having Valenzuela with 100% of its pavement, 43.52% failed condition for Gaabucayan, and 47.40% for the Mambato.

Table 2 shows the total number of pavement affected by the different types of distresses in percentage. Valenzuela Street has a total of one hundred twenty eight (128) pavement sections. From the table, the type of distress that is dominant on the area is Fatigue Cracking where the distress is present to all pavement sections (100% are affected). Raveling, with one hundred twenty seven (127) affected pavements or 99.22% also dominates Valenzuela Street, followed by block cracking with 68.75%. On the hand, Gaabucayan Street consists of a total of one hundred forty one (141) pavement sections. Fatigue cracking also dominates the area with a total of seventy (70) affected sections or 49.64%, followed by Raveling with 48.94%. Mambato Street has eighty seven (87) pavement sections and Raveling exists to eighty one (81) of the sections or 93.10% affected pavements. The existence of Potholes and Transverse cracking also dominate the area, both having fifty seven (57) affected pavements or around 66%. Among the distresses present on the pavements around Agora Market, Rutting contributes less to the condition of the pavements prior to the severity of the distresses. As to Valenzuela and Gaabucayan Streets, only one (1) pavement is subjected to Rutting with 0.78% and 0.71%, respectively. For Mambato Street, four (4) pavement sections are subjected to Rutting with 4.60% of the total pavement sections of the street.

Also, shown in Figure 3 is the Straight Line Diagram (SLD) which summarizes the current situation of the pavement around Agora Market prior to the rating scale on Table 1. It is clear enough that the Valenzuela Street has the worst level of severity having 100% of the entire pavement as totally distressed or is in its "Failed" condition. Valenzuela is the main access road where almost all types of vehicles, as enumerated from the AADT, especially huge cargo or trailer trucks, enter Agora Market. Also, Mambato Street contains pavements that are in "Failed" condition due to the fact that numerous large and small buses, passenger car and passenger utility vehicles access the road. For Gaabucayan Street, the first eighty (80) pavement sections were still under "Good" condition. These sections were from the other end of the road (perpendicular to the Corrales Extension) and not around the Agora Market. The road is known as the Gaabucayan Extension. It is in its good condition because the main users of this road are motorcycles, motor-tricycles, and private vehicles which nearly do not contribute severity to the distresses since it has light to medium weight compared to large vehicles. However, the eighty-first (81^{st}) pavement which approaches the main Gaabucayan Street (circumferential road of Agoras Market) illustrates that the pavement starts to fall under "Failed" condition because all vehicles that access Valenzuela Street will also be using or passing the Gaabucayan Street since Agora Market alone is a one way – four lanes path. Thus, buses, private and public vehicles, huge cargo and trailer trucks, worsen the condition of the road pavements.

Figure 2 shows the overall rating per street in terms of percentage. From the graph, it shows that all pavements of Valenzuela Street have the worst level of severity having 100% of entire pavement as totally distressed or is in its failed condition. On the other hand, the severity level that dominates Gaabucayan Street with 43.52% of the entire pavement is a failed condition, however, 41.71% of street is still in its good condition, 5.48% of the street is poor, 5.10% gives a satisfactory rating , 2.83% is fair, and 1.37% is very poor. Whilst in

Mambato Street, failed pavement condition dominates the entire street with 47.40% of the entire pavement is affected, 20.45% is poor, 16.08% is very poor, 11.23% is in its serious condition, 3.70% is satisfactory, and only 1.14% of the Mambato Street is good.

4.2 Pavement condition of Agora market for present volume of traffic

Road pavements are designed to last a life period of twenty five (25) years for Portland Cement Concrete pavement (PCCP) and ten (10) years for Asphalt Concrete Pavement (ACP) (DPWH, 2011). Agora Road in Barangay Lapasan started on 1983 where the City Engineers Office-Cagayan de Oro (CEO-CDO) had been the agency responsible in designing and implementing the road construction. It is an arterial road with a range of low to high level of service during non-peak hours. The road is composed of PCCP therefore it is expected to last for twenty five (25) years.

As shown in Figure 2, most roads around Agora Market are in their very poor, serious and failed condition. Thus, the pavements along the road would worsen the distress severity case due to daily traffic volume since loaded cargo trucks and utility vehicles are the main road users.

4.3 Pavement condition of Agora market for Future Volume of Traffic

Table 3 summarizes the number of pavements which were affected by various distresses and are categorized according to the levels of severity. The current pavement condition of Agora Market shows that the “failed” condition on every section dominates per street. All pavements of Agora are in “failed” condition. As for Gaabucayan and Mambato streets, about half of the number of pavements per street has a rating of “failed”. Considering the volume of traffic that these loads carry, the pavement condition would turn out worse in the future.

To verify whether or not the current condition be able to accommodate the future traffic volume, ratio and proportion was conducted between the future projected year (say five years from now) over the current year and the projected future PCI over the current PCI of the pavement.

$$\frac{ProjectedYear}{CurrentYear} = \frac{ProjectedPCI}{CurrentPCI} \tag{3}$$

As to the current year, 2014 is used since the survey was conducted on July 2014. The calculated projected PCI for: (a) Valenzuela Street is 155.33, (b) Gaabucayan Street is 74.22, and (c) Mambato Street is 131.89.

Based on the anticipated values of PCI for the next five (5) years, the general average pavement condition of the entire Agora Market can be categorized under Failed Condition. Therefore, it can safely be concluded that the current pavement condition cannot anymore accommodate the future traffic volume considering the do-nothing scenario.

5. CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusion

The Pavement Condition Index (PCI) calculated for Valenzuela Street has the worst level of severity having 100% of the entire road are totally distressed and is in its failed condition;

while in Mambato and Gaabucayan Streets have 47.40% and 43.52% failed pavements respectively.

Based on the survey conducted by the researchers, an average of 73.20% of the total pavement along Agora are ‘’failed’’ to ‘’very poor’’ conditions. This percentage implies that the circumferential road along Agora Market must minimize their vehicular loading to sustain the present volume of traffic. Thus, due to the levels of severity of the distresses obtained through Pavement Condition Index (PCI), the researchers safely concluded that the entire circumferential road will be totally reconstructed

5.2 Recommendations

5.2.1 Pavement improvement

To be able to attain better pavements, improvement must be applied: (a) sub grade and material improvement; (b) adoption of low-cost reconstruction and repair. Pavement repairs, according to the researchers’ calculated Pavement Condition Index (PCI), shall be applied when indices range from 0 to 40 (Good to Fair). There are several ways on repairing distress pavement. Specific treatments include (1)joint resealing which minimizes water infiltration and prevents intrusion of incompressible in the joints; (2)slab stabilization which includes under-sealing, sub-sealing, or pressure grouting which to fill voids beneath the slab; (3)partial-depth repairs that stores the structural integrity of the pavement and improve its overall ride quality; and (4)full-depth repairs that restores the rideability of the pavement to prevent further deterioration of the distressed area. However, when the PCI ranges from 71 to 100 or above (Serious to Failed), the distressed pavement shall undergo reconstruction or replacing the entire pavement and replacing it with an equivalent or increased pavement structure and integrity, prior to the new innovative pavement design. In monetary terms, modified Financial Benefit Cost Analysis can also be used since it is considered as a systematic analysis of translating any decision where evaluations are based on advantages (benefit) and disadvantages (cost) of the project.

5.2.2 Rerouting

According to Wahyudi, et.al (2013), results of damage factor analysis for each class of freight vehicles indicate that vehicles which are categorized according to the classification prior to the vehicle weights, contribute to pavement damage. Vehicle distribution is necessary in Agora Maket, Brgy. Lapasan, Cagayan de Oro City because almost all types of vehicles especially buses and trucks, access the road. They contribute loading onto the pavement which is one of the factors why pavement distresses exist. Large vehicles such as semi-trailer trucks (1-1 and 1-2), 4-axle trailer truck, and 5 and above-axle trailer trucks enter and exit Valenzuela Road, which is the most distressed circumferential road of Agora Market with an overall rating of its pavement condition: “Failed”. Thus, to reduce loading and to minimize the severity of the existing distresses around Agora Market, there must be a control of vehicles that will access the area. Large vehicles, as enumerated, may access through Osmeña Extension towards their destination, either to the Solid Shipping Lines Corp., which is directly across the road, to the Agora Market, or to Corrales Extension. Strict control on overloading truck by controlling limited truck load is required since overloading is very often assumed as the factor that affects the level of pavement structure damage (Rusbintardjo, 2013)

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APPENDIX

RATING QUALITY	COLOR	RATING QUANTITY
GOOD		0 - 10
SATISFACTORY		11 - 25
FAIR		26 - 40
POOR		41 - 55
VERY POOR		56 - 70
SERIOUS		71 - 85
FAILED		86 and above

Table 1. PCI Values Ranges for PCCP

Table 2. Number of Affected Pavement Per Street (%)

	Valenzuela	Gaabucayan	Mambato
Patching	10.94	11.35	37.93
Block Cracking	68.75	13.48	35.63
Pothole	7.03	21.28	65.52
Raveling	99.22	48.94	93.10
Edge Cracking	0	38.30	0
Longitudinal Cracking	49.22	15.60	59.77
Transverse Cracking	16.41	14.89	65.52
Fatigue Cracking	100	49.64	35.63
Alligator Cracking	4.69	0	0
Rutting	0.78	0.71	4.60

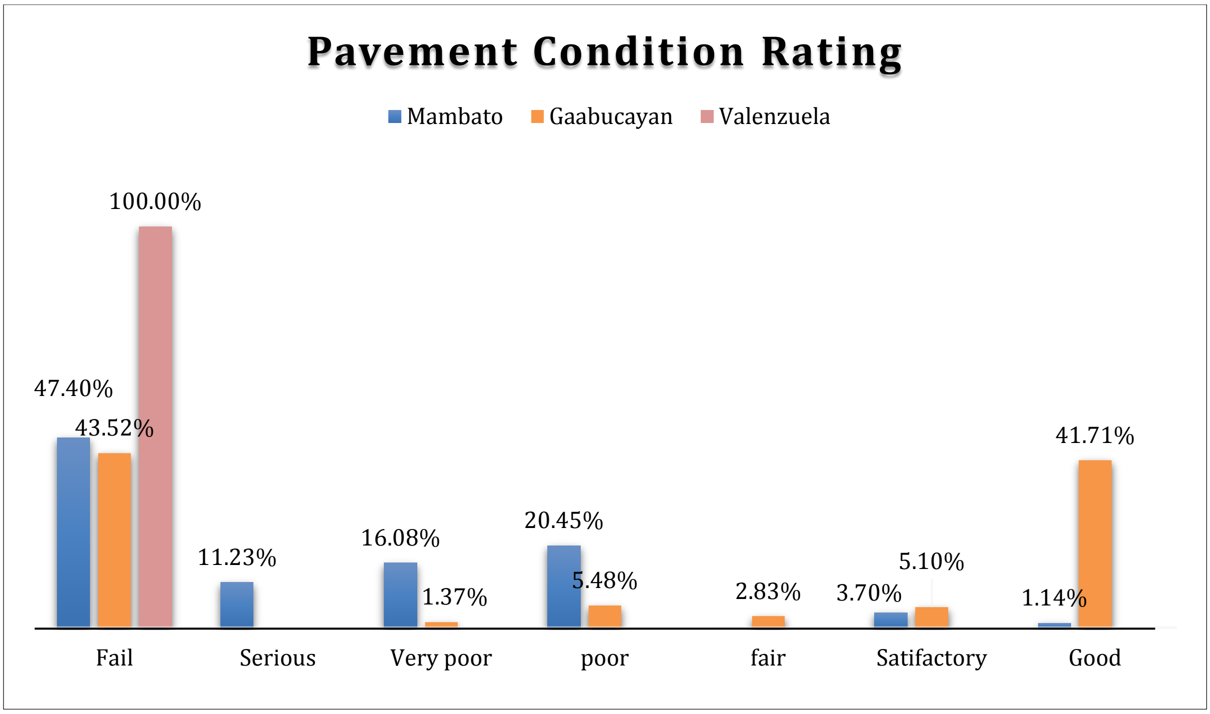

Figure 2. Pavement Condition Rating

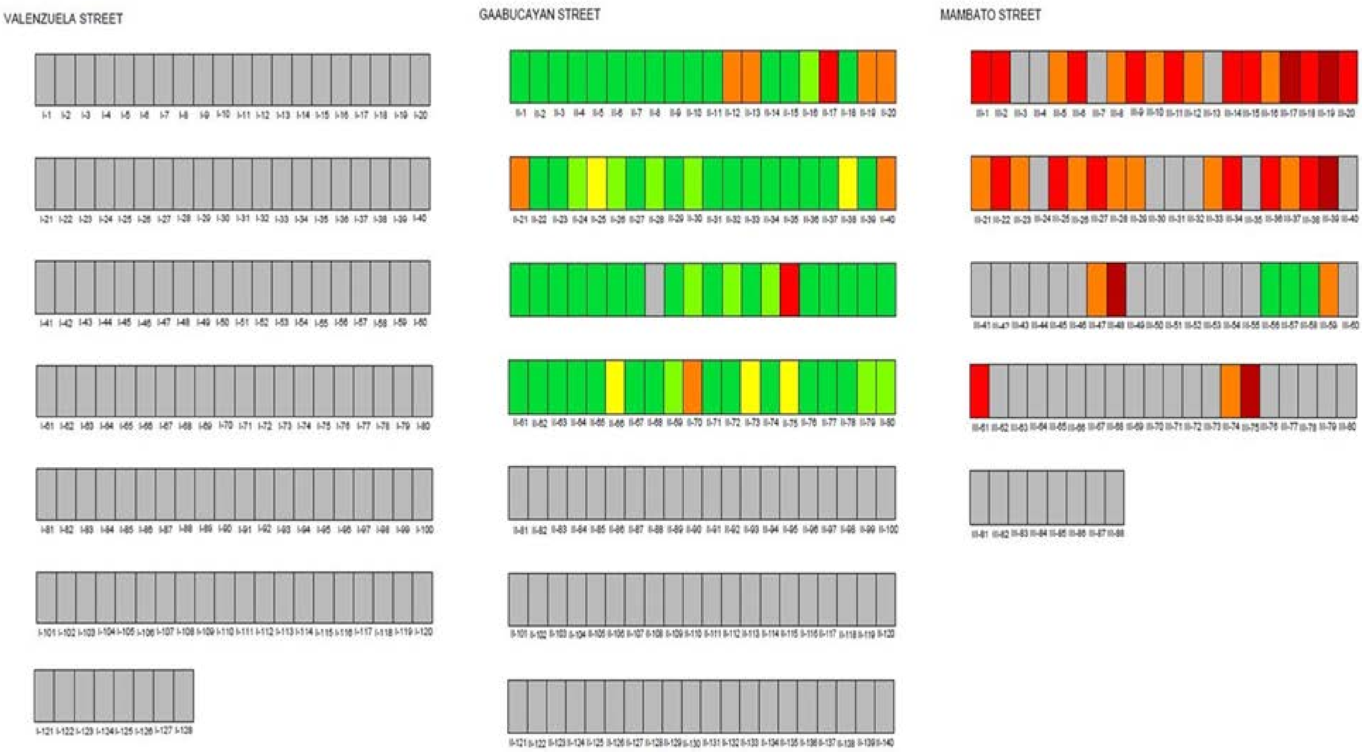

Figure 3. Straight Line Diagram

Table 3. Number of Pavements Affected by Distresses

Road Name	Levels of Severity							Total No. of Pavements
	Good	Satisfactory	Fair	Poor	Very Poor	Serious	Failed	
Valenzuela	0	0	0	0	0	0	128	128
Gaabucayan	54	11	5	7	2	0	62	141
Mambato	3	1	0	15	14	7	47	87

REFERENCES

Wahyudi, W., Sandra P.A., Mulyono, A.T. (2013) Analysis of Pavement Condition Index (PCI) and Solution Alternative of Pavement Damage Handling Due to Freight Transportation Overloading (Case Study: National Road Section West Sumatra Border – Jambi City). *Proceedings of Eastern Asia Society for Transportation Studies, Vol. 9*

Gatot Rusbintardjo. (2013) The Influence of Overloading Truck to the Road Condition. Proceedings of Eastern Asia Society for Transportation Studies, Vol. 9

Goodspeed, C., Schmeckpeper, E., & Lemieux, R. Road Surface Management System. . Retrieved , from http://pavementmanagement.org/ICMPfiles/1994048.pdf

Gavilan, M., Balcones, D., Marcos, O., Llorca, D., Sotelo, M., Parra, I., et al. Adaptive Road Crack Detection System by Pavement Classification. . Retrieved , from www.mdpi.com/1424-8220/11/10/9628/pdf

Mustaffar, M., Ling, T., &Puan, O. Automated Pavement Imaging Program (APIP) for Pavement Cracks Classification and Quantification - A Photogrammetric Approach. The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences, Vol. XXXVII. Part B4., 6. Retrieved , from http://www.isprs.org/proceedings/XXXVII/congress/4_pdf/64.pdf

Kuennen, T. Correcting Problem Concrete Pavements. Road Science, 1-7. Pavement Cracking: A Failure Indicator Of Your Roads. . Retrieved , from http://www.clrp.cornell.edu/tip_sheets/pdf/cracking.pdf

Adaska, W., &Luhr, D. Control of Reflective Cracking in Cement Stabilized Pavements.Cracking in Pavements - Mitigation, Risk Assessment and Prevention, 8. Retrieved, from http://cement.org/pavements/cracking.pdf

Pavement Distress Identification Manual for the NPS Road Inventory Program (Cycle 4 ed.). (2009)

SDDOT'S Enhanced Pavement Management System . (2009, November 4). . Retrieved , from http://www.sddot.com/resources/Manuals/DistressManual.pdf

ARCADIS. Advanced Inspections Project Innovative Technologies to Improve Highway Condition Monitoring. Report of the Innovation Projects Highway Maintenance RWS-DVS; Available online: http://www.rijkswaterstaat.nl/images/Advanced%20Inspection%20Project%20 Final%20Report_tcm174-283988.pdf (accessed on 27 August 2011).

Furness, G.; Barnes, S.; Wright, A. Crack Detection on Local Roads—Phase 2; Available online: http://www.ukroadsliaisongroup.org/pdfs/07-03-19%20TTS_Crack_Report_Final_190307.pdf (accessed on 27 August 2011).

Subirats, P.; Fabrre, O.; Dumoulin, J.; Legeay, V.; Barba, D. A combined wavelet-based image processing method for emergent crack detection on pavement surface images. In

Proceedings of the XII European Signal Processing Conference, Vienna, Austria, 6–10 September 2004.
Battiato, S.; Stanco, F.; Cafiso, S.; di Graziano, A. Adaptive imaging techniques for pavement distress analysis. Commun. SIMAI Congr. 2007, doi: 10.1685/CSC06016.
Salari, E.; Bao, G. Pavement distress detection and classification using feature mapping. In Proceedings of the IEEE International Conference on Electro/Information Technology, Normal, IL, USA, 20–22 May 2010.
“Distress Identification Manual for the Long-Term Pavement Performance Program”, Publication No. FHWA-RD 03-031, June 2003
Pavement Maintenance, David Orr, PE, Cornell Local Roads Program, March 2006 www.clrp.cornell.edu/workshops/manuals/pavement_maintenance.pdf.
Larsen, H.J.E, G. Hildebrand and R.A. Macdonald (2002), Economic Evaluation of Pavement Maintenance PAV-ECO, Road Directorate, Danish Road Institute, Denmark.
Zaniewski, J. and M. Mamlouk (1999). Pavement Preventive Maintenance: Key to Quality Highways. Transportation Research Record, Vol. 1680, Transportation Research Board, National Research Council, Washington, D.C., USA, 24-29.
Watanatada T., C.G. Harral, W.D.O. Paterson, A.M. Dhareshwar, A. Bhandari , and K. Tsunokawa (1987). The highway design and maintenance standards model, volume 1: Description of the HDM-III model, The Highway Design Strategies for Highway and Maintenance Standards Series. Baltimore: Johns Hopkins for the World Bank.