Navigational Digital Maps - Malaysia Road Network

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***Abstract*—Car navigation system (CNS) has become one of the popular accessories amongst driver in Malaysia. Currently all CNS component are imported except digital maps that been produce by local map provider referring to document ISO 14825:2011 - Intelligent transport systems - Geographic Data Files (GDF) – GDF 5.0. Even thoughthe document have an intensive guideline but most of it does not suit Malaysia road network. This paper discussing about type of access restriction and prohibited manoeuvre classification that exist in Klang Valley road network. Sanyo CNS unit with a 2007 Klang Valley digital maps used to conduct a series of site investigation. Result from the investigation shows that there are six (6) type of prohibited manoeuvre exist in Klang Valley area. The intention of this investigation is to incorporate Malaysia road model with the GDF document so GDF conversion and quality checking tools can be develop according to Malaysia road model. This can avoid error in CNS maps due to human operator interfere.**

***Keywords*—car navigation system; digital maps; prohibited manoeuvre; divided junction; grade separated crossing**

I. INTRODUCTION

Automotive is one of the most profitable industries in Malaysia. Since last 3 decade, automotive has established as one of the Malaysia major transactions. Recent economic ties with United States of America (USA) through FTA has opened Malaysia automotive market into more car brand. Though there is an opinion that too many imported car will eventually threaten the national car industries but on the other hand, this imported car actually is doing a great job to challenge national car industries to become more competitive. For price and performance, no one can deny the benefit car buyer can get from this competition. Apart from high performance imported car, this competition also offers Malaysia buyer automotive accessories like navigation system. Automotive market in country like Japan or USA has utilizing navigation system since 1980 and today, almost every new car already been equipped with navigation system. For Malaysia market, navigation system starts by 1990 by BMW, followed by Volvo and Range Rover. In 2005, GARMIN portable navigation system hit the Malaysian market and became the trend setter for navigation system industry. Cheap, portable and numerous Point of Interest (POI) make GARMIN the best seller navigation system in 2005 [1]. Since then, navigation system in Malaysia becomes popular in automotive industries. Started with raster map origin from scanned maps that been overlay with Global Positioning System (GPS) back in 80's, today navigation system offer much function with audio video function, games like playstation or Xbox, real time traffic info, interactive assistance for emergency and elderly (remote set up) and a lot more. Device that previously considered as a luxury nowadays become standard accessories for most of car maker [2]. In Western Europe, around 14.4 million portable navigation systems were sold during 2007. Research in Netherland on 2006 shows that, out of 1,144 car drivers, 28% owned a navigation system. Over 35% of the car drivers in possession of a navigation system used it on 20% of their trips and over 15% used it on 80% of their trips. The system was mainly used for unfamiliar destinations [4]. It is convenience to have a visual and audio guidance when cruising at unfamiliar destinations, plus driver feel more confidence knowing that guidance are based on mapped traffic regulations that uploaded into the system. This sense of confidence and convenience could be the reasons for the drivers who have a navigation system to drive more kilometers per year than the group without such a system: of those who have a system, 60% drive more than 20,000 km per annum; of those without a system, 40% drive more than 20,000 km per annum [4]. Navigation system today not only limited to car but also vehicles used in professional services, such as taxis, buses, ambulances, police cars, and fire trucks. These vehicles are equipped with navigation systems that not only show the current location but constantly communicate the vehicle location to a monitoring center as well. Operators at the center can use this information to direct the vehicle fleet as efficiently as possible [5].

In Malaysia, navigation system evolves rapidly. Though no official study been establish on quantity of navigation systems in Malaysia currently, but number of outlet offering navigation system keep increasing. Even, car accessories outlet these days also has navigation

system on the shelf. This trend might be influence by driver that exposed to technologies and gadgets at the young age.

A. Car Navigation System (CNS)

Navigation system used in this research is Sanyo original equipment manufacturer (OEM) car navigation system (CNS). This system comes in bundle with audio video system for the car. Other than OEM units, there are portable navigation system and mobile navigation system. Amongst all, portable navigation system is the most popular because it is cheap, portable and does not require any space on the car dashboard. As for mobile navigation system, it relatively new in Malaysia and require additional paid subscription from telecommunications provider.

B. CNS Component

There are three elements in CNS, Global Positioning System (GPS), navigation software and digital maps. GPS function as a locater, its provide coordinate to the CNS as the car moving. This coordinate later used to match car location with the digital maps. Drivers have no control for this component so reliability of the GPS signals very much depending on the device quality. For area with poor GPS coverage like urban canyon, to enhance reliability, dead reckoning using distance data from sensors attached to the drivetrain, a gyroscope and an accelerometer can be used, as GPS signal loss or multipath can occur due to the urban canyons or tunnels [6].

Navigation software is to provide assistance to the driver. It is navigation software that contains algorithm to calculate routing for driver to reach destination. Driver set destination into the CNS, navigation software will calculate road that accessible to reach the destinations. Start point for route calculation can be from location or car current coordinate. The algorithm takes into consideration of traffic regulation along the way to reach destinations. If in situation driver miss the junction or turn point, navigation system will recalculate routing based on current car GPS coordinate. Point of Interest (POI) search is the most popular application for CNS. All these function however has vary algorithm based on CNS device brands. More complex algorithm and faster search function might cost more. For route calculation, there are 3 basic routing options, Shortest Path/Fastest Route, Mostly Highway and Optimize Route (non highway) [2].

Digital maps for CNS is a navigation geographical data that maps out road network information, expresses the topology relation and the attribute information of road network with the purpose of conducting path planning and form guidance [7]. It shows driver the surrounding and provides landmarks or feature at particular location. This digital map has undergone map matching process to ensure smooth and seamless visual as the car moving. This is the only component in the CNS that been produce locally. The problem with this digital maps is it is often contains out of date information. Ideally, for big cities like Klang Valley, CNS owner need to update their digital maps every 6 months due to rapid changes in traffic at city area. For suburban or village, once in two years is sufficient. The only things that hold back the updating is the cost. It is quite expensive since the map provider for CNS in Malaysia is still limited. Currently there are four stages in producing navigation digital maps - data collection, digitizing, quality check and map update.

C. Data Collection, Digitizing and Up Dating

Digital maps loaded into the CNS already undergone at least three out of four mapping process - data collection, digitizing and quality check. The most convenience way to collect data these days is by using remote sensing techniques. Remote sensing image can cover up to 60% of data needed to produce CNS digital maps. The 40% data are collected using GPS tracking and on ground survey. 60 % remote sensing data cover two types of data. One is to identify the location of junction and another one is to digitize basic shape of the road. Marking a junction from remote sensing image is possible for non elevated road. Since remote sensing image already geocoded and georeferences, draught person just digitize the location of the junction to add spatial and attribute data [8]. GPS tracking and ground survey needed when some spatial and attribute data fail to be extract from remote sensing image. During GPS tracking and ground survey, surveyor bring paper map called base map to the site and collect attribute that cannot be derived from the remote sensing image [8] like elevated road, road signage hidden under the tree or traffic regulation painted in the road that been covered by elevated road. Circle in Figure 1 shows the location of a signboard for prohibited maneuver; driver from road A cannot turn left since it is a one way road. This signboard did not appear in the remote sensing image therefore it cannot be digitized. Surveyor marked this junction on the base map. Apart from that, surveyor also required to verify attribute that been digitized from the remote sensing image.

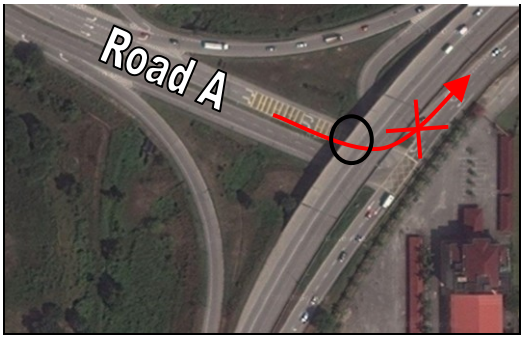

Figure 1. Hidden prohibited manoeuvre signboard

D. Accident and Quality Checking

One of the concerns when selecting a CNS is safety. This issue is a popular question when buyer negotiating with the CNS dealer. Question like does the map correct? Or does the map already incorporate road construction at the new intersection? For navigational maps, the most stringent area is at intersection. Modern road networks can provide a relatively safe environment for motorists and

pedestrians. However, depending on the region and country, between 30% and 60% of all injury accidents and up to one third of the fatalities occur at intersections. This is due mainly to the fact that accident scenarios at intersections are among the most complex ones, since different categories of road users interact in limited areas with crossing trajectories [9]. When more than one driver meets at the intersection, it requires some degree of understanding on the sequence. Here the conflict will happen when any of the drivers fail to follow the queue. A conflict is defined as an observable situation in which two or more road users approach each other in time and space to such an extent that there is risk of collision if their movements remain unchanged [10]. Accident cause or trigger by CNS currently still low and at some country for example Malaysia, accident cause by CNS are considered driver fault. This research able to investigate two main reasons CNS cause an accident. The first reason is due to out of date maps. For example roads those previously two ways (dual carriageways) have been change into one way. Another example is the situation when a road is under construction. Road construction happens all the time and everywhere, it is difficult to update digital maps every time road is closed for construction and update again after road are opened back after the construction. Since CNS did not have the latest information on the road closure due to construction, it will calculate the road as part of the routing and this will guide the driver to use this road to reach the destination and driver that following CNS guidance are at risk of traffic misfortune. Another reason is maps been wrongly digitize or data wrongly collected. SWOV, Institute of Road Safety Research in Netherlands report that out of date or incorrect information in the navigation system can lead to wrong decisions: undesirable or unsuitable routes (through traffic via streets in residential areas, heavy goods vehicles through town centres) or even incorrect routes (one-way traffic, physical obstructions, roadworks, roads with height limitations, viaducts and bridges unable to bear the vehicle's weight) [11]. Other than those two reasons, there is also a study done in 2008 shows that driver using CNS can be distracted and pay less attention to the road and surrounding traffic [12].

These two accident can be minimize if map provider willing to invest more into the quality checking (QC) procedure. There are two type of quality checking that been imposed into the CNS digital maps. It is spatial quality checking and attribute quality checking. Spatial quality checking deals with the spatial (object) information in the digital maps. Though there are hundreds of spatial quality checking can be imposed, this paper discussing two of it. The first spatial quality checking is on the road shape. It is well understood that road shape were trace from the remote sensing image and draught person will trace the road shape exactly like the image. Error that can happen here is road curve been digitized more than 15°. This is the most common case. Maximum angle between the road that allowed is not more that 15°. This to avoid the CNS interpret this curve as a turn. This type of QC is easy to apply since the topology of the road network is connected to each other. Another quality checking for spatial data is to guarantee at the part of road intersects with the other road, when grade is same, guarantee road is divided. This is the case where two or more roads are intersecting with each other. This is definitely a violation in any digitizing rules. For this case, the intersection is necessary if the road is a flyover. This situation is known as grade separated crossing. Figure 2 shows an area at Sg.Penchala Lebuhraya Damansara Puchong (LDP) and Lebuhraya SPRINT (SPRINT) crossing each other in in a massive grade separated crossing [8].

Attribute quality checking also known as logic quality checking and it is conducted in 3 phase. First phase is listing out the relationship of the entire attribute for the entire feature. This task is important to ensure all feature attribute has a connection with at least one feature. Second phase is drawing the entity relationship model (ERM). This model function as a spider web, any constraint or rules that need to apply for each attribute will have to satisfy the entire web. Last stage is enforcing the quality checking to the database. Example of logic quality checking; Case 1: When divided junction is existing, guarantee all the corresponded prohibited maneuver are exist. In this case, regardless the junction is not crossable due to existence of physical divider or double line mark, a prohibited maneuver relationship need to be created. This to avoid CNS calculates routing through this forbidden junction. A mistake here can cause a serious accident since the driver might ramp into another car or road divider. Case 2: If the road is closed for construction then attribute direction of traffic flow must be negative in both directions. This will notify the CNS not to take into consideration of this road when doing route calculation. Case 3: Guarantee that direction of traffic flow and prohibited maneuver relationship is not contradict. In this case, the road will become dead end. All these cases are originated during digitizing. It is difficult to check this error manually since the volume of data is high. Therefore it is recommended to conduct an automation batch processing using program like SQL.

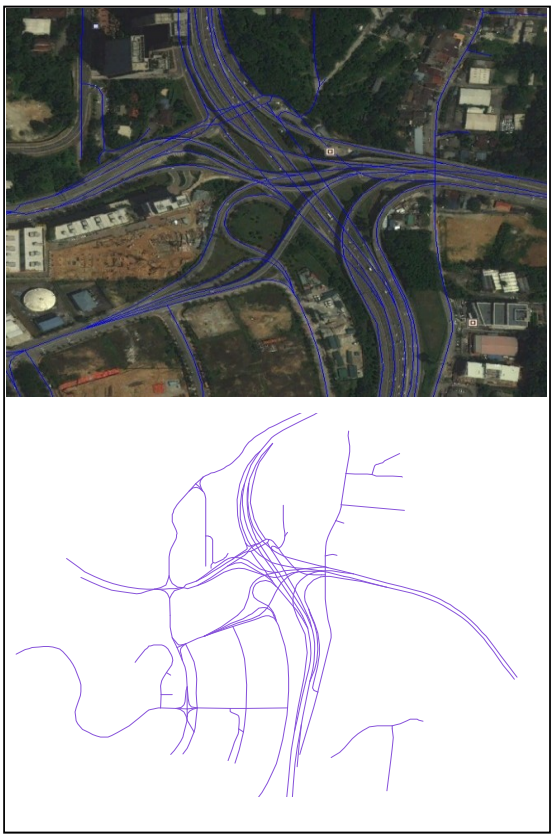

Figure 2. Massive Grade Separated Crossing for multiple elevated road

II. ACCESS RESTRICTION

Access restriction is a rules that been implied into the navigation software to prevent certain road carrying specific attribute data being calculated as part of the routing. This restriction been imposed based on certain reasons; for example road closed, under construction, direction of traffic flow, narrow curve and many more. For CNS, access restrictions were representing by three relationships and three attribute data. Relationship that involve is prohibited manoeuvre (2103), divided junction (1030) and grade separated crossing (2200). Three attribute data are direction of traffic flow (DF), Validity Period (VP) and Vehicle Type (VT)

A. Prohibited Manoeuvre

Prohibited manoeuvre is a relationship indicates access restriction from a road segment to another road segment [13]. In ISO 14825:2011 - Intelligent transport systems - Geographic Data Files (GDF) – GDF 5.0, prohibited manoeuvre coded as relationship (2103). It is to prevent navigation software calculates routing opposite direction of traffic flow or entering restricted road. It is crucial to identify classification of prohibited manoeuvre to be imposed in the navigation software inside CNS. This classification should be able to cover all type of possible prohibited manoeuvre that exist in Malaysia road network. This to ensure that navigation software able to calculate routing sequence based on rules that been set in the digital maps quality checking. This research classifies six types of prohibited manoeuvre currently exist in Klang Valley.

Research area consists of seven districts in greater Klang Valley - WP Putrajaya, WP Kuala Lumpur, Ulu Langat, Sepang, Petaling, Gombak and Klang. Figure 3 show road network inside the research area coverage. Total area is 3458.2km^2 with total length of road network is 4381926km.

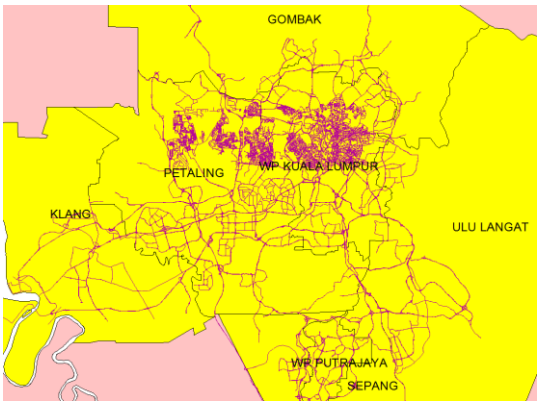

Figure 3. Road network across seven district in Klang Valley

Classification of prohibited manoeuvre in the research area should be able to represent almost all the prohibited manoeuvre in Malaysia since Klang Valley is the most massive traffic network in the country. First type of prohibited manoeuvre is; Unable to turn because of traffic regulation. Prohibited manoeuvre in figure 4 and 5 exist at intersection that have visible or logic prohibited manoeuvre traffic regulation. Visible traffic regulation normally presented by signage of no entry or do not enter.

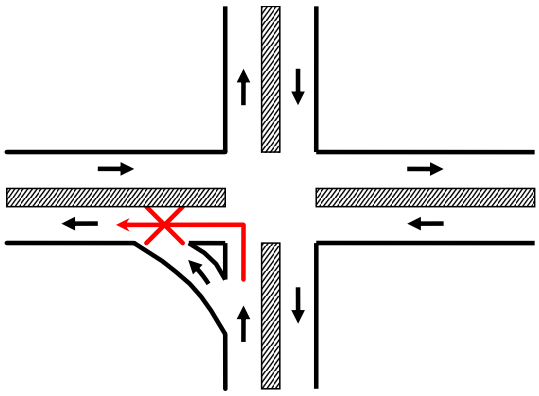

Figure 4. Junction with logic prohibited manoeuvre traffic regulation

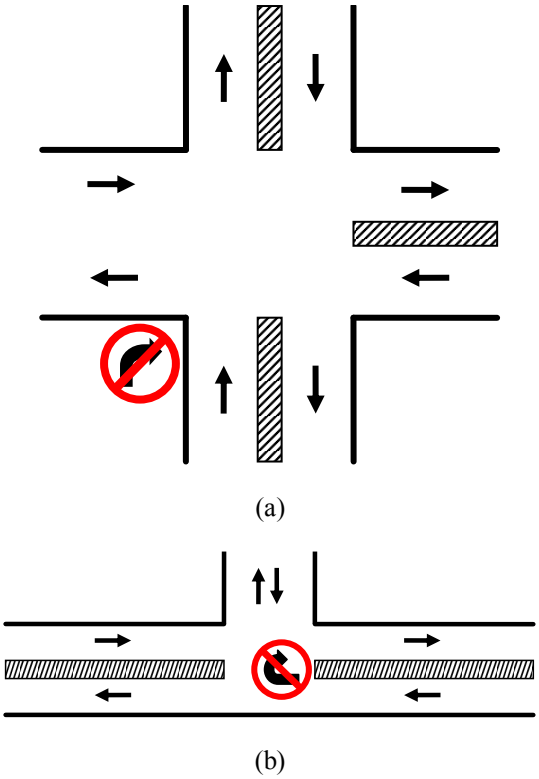

Figure 5. Junction with visible prohibited manoeuvre traffic regulation

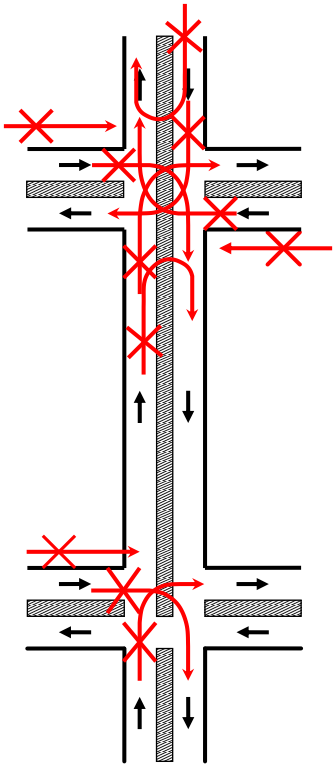

Figure 6. Prohibited manoeuvre because of physical divider

Figure 6; Unable to turn because of physical divider. This condition exists at the junction with the divider physically visible to the driver.

Figure 7; Prohibited to turn because of security restriction. This condition normally exist at the access road to facilities or services exclusive of access to basement parking. In this condition, normally facilities will have limited operating hours therefore access to facilities premises is limited only during operating hours. There also cases where permanent prohibited manoeuvre must be digitize i.e access road to parliament or army camp. This type of premises, prohibited manoeuvre is compulsory due to security reason.

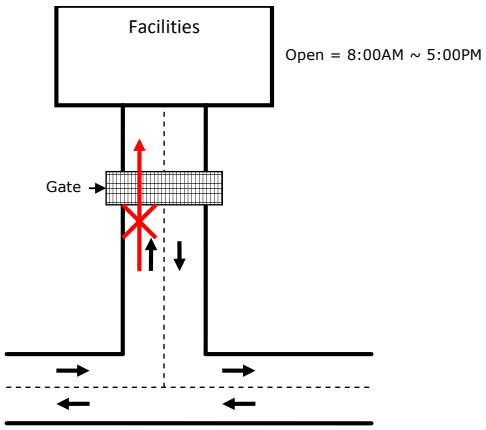

Figure 7. Prohibited manoeuvre because of security restriction

Figure 8; Unable to turn because there is no U-turn signboard for Multiple Carriageway. This condition exist at the multiple carriageway regardless class of road either federal, state road or street. Multiple carriageways is a road whereby vehicle can access in both direction.

Direction of traffic flow for this type of road is positive in both directions.

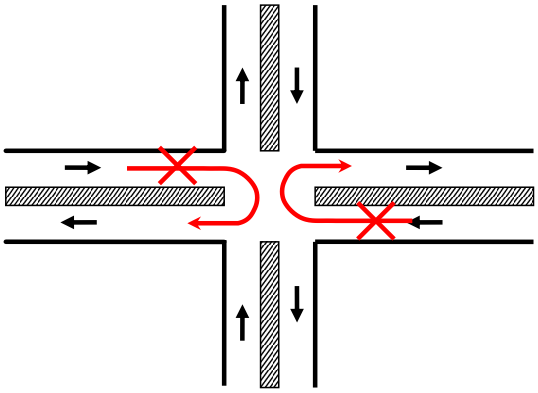

Figure 8. Prohibited manoeuvre because there is no U-turn signboard for Multiple Carriageway

Figure 9; Unable to turn because of narrow road angle. This condition does not have specific signage indicate prohibited manoeuvre but the shape of the road is classify as dangerous for vehicle turning.

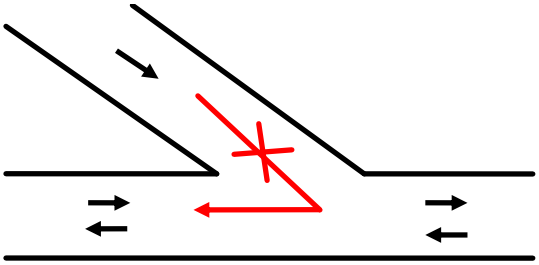

Figure 9. Prohibited manoeuvre because of narrow road

Figure 10; Unable to turn because of direction of traffic flow. This condition exists at almost every junction regardless single, dual or multi carriageways. Since all the road element has been assigned with direction of traffic flow (DF) attribute, no prohibited manoeuvre relationship are required.

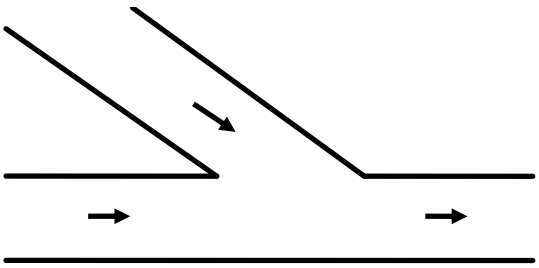

Figure 10. Unable to turn because of direction of traffic flow.

B. Divided Junction

Divided junction is a relationship that describes the availability of divider on a road segment that prevents car from crossing to another road or direction [13]. In ISO 14825:2011 - Intelligent transport systems - Geographic Data Files (GDF) – GDF 5.0, divided junction coded as relationship (1030). It is to prevent navigation software calculates routing consisting two or more road that have divider in between either physical divider or traffic regulation. There are two conditions of divided junction; (1) Continuous divider that required both divided junction (1030) and prohibited manoeuvre (2103) relationship. (2) Divider that has a break in between and it only obstruct one side of the traffic flow, only Prohibited Manoeuvre (2103) is required [2]. Figure 11 shows case example for divided junction at Bukit Bintang, Kuala Lumpur. Here, the junction has a physical divider that forbid driver to make a turn. Normal arrow indicates road that can be accessible and arrow with cross indicate prohibited maneuver. Driver from road 1 can only turn to road 3.

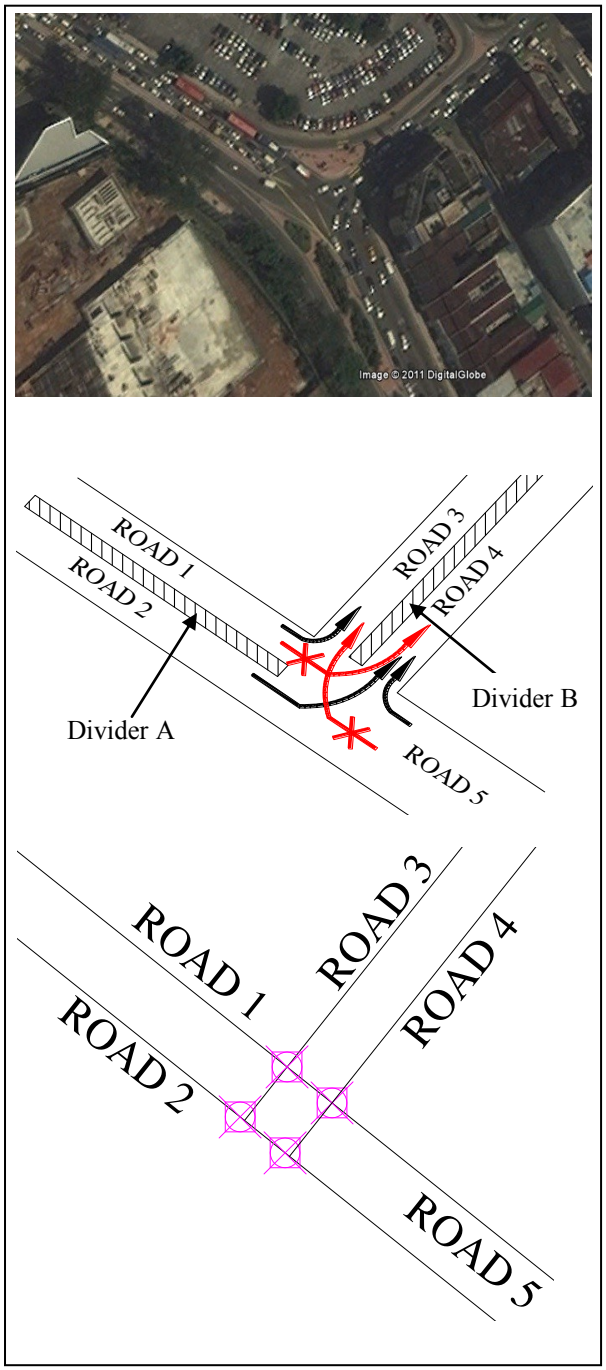

Figure 11. Divided junction.

Divider B has created one prohibited maneuver since it is dangerous for the driver to access road 4 from road 1. At the same time, there is no need to create prohibited maneuver from road 1 to road 5 since road 5 already been define as one way in Direction of Traffic Flow attribute. The same model applies to prohibited maneuver from road 5 to road 3, road 1 and 2. For accessibility from road 2, drivers were allowed to turn into road 4 only. Existence of divider A and B created prohibited maneuver for driver from road 2. CNS will calculate all along road 2 as a divided road therefore the routing algorithm will prohibit turning direction for road with the existence of divider.

C. Grade Separated Crossing

Grade Separated Crossing is a relationship that defines the association between two transportation elements that are crossing at different grades. The transportation element can be either a road element or a junction**.** It also represents the situation where a transportation element passes a tunnel or bridge [13]. Therefore there must be at least two (2) component features in the grade separated crossing relationship which is transportation element and transportation element or transportation element and brunnel. In this research, it is found that there are six (6) grade separated crossing modelclassification exist in Klang Valley road network. There are Road and Bridge, Road and Tunnel, Road and Road, Road and Junction or Junction and Road, Road and Bridge and Road, Road and Tunnel and Road, lastly Road, Road and Road. In some area especially for intersection between multiple highway and federal road, two or three modelclass of grade separated crossing can exist. Figure 12 shows elevated road element with a existence of brunnel. Road 1, 2 and 3 passing through a tunnel and road 100 is crossing over the tunnel. Vertices of the upper and lower level of road element coincide at the same x and y location to indicate upper and lower road. Though the feature overlapping sequence in Figure 12 is road, brunnel and road but for navigational digital maps, it was digitized as road, road and brunnel. For this case, it is not necessary to create prohibited maneuver since road 100 is one straight line without any junction in the middle. Therefore CNS will not be able to create any routing connecting road 100 and other road below it.

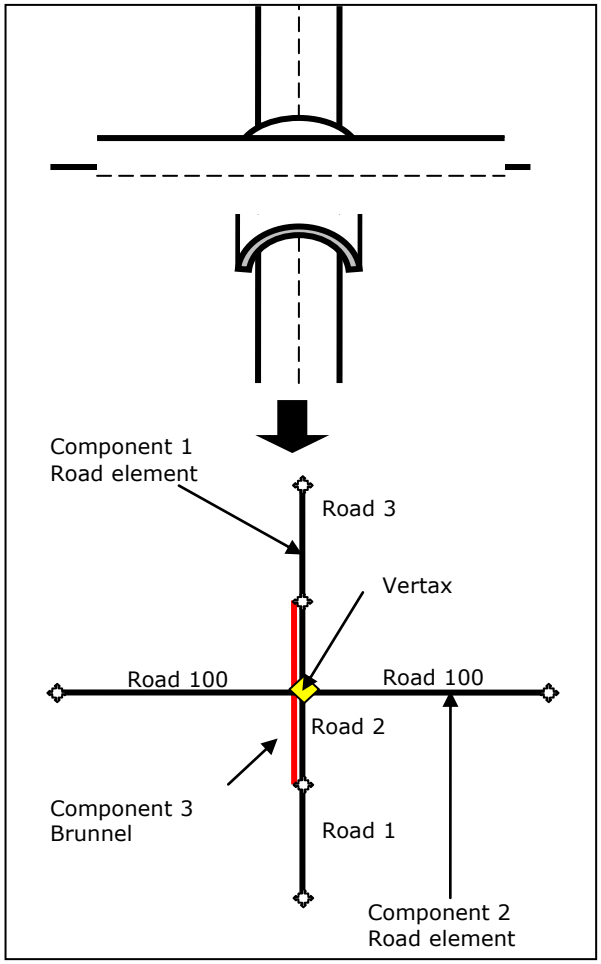

Figure 12. Grade Separated Crossing for road, brunnel and road

D. Direction of Traffic Flow, Validity Period and Vehicle Types

Direction of Traffic Flow is the traffic flow direction for a road element. It is defined depending on the traffic regulations and digitizing rules. There are four conditions; (1) Traffic is allowed in both directions. (2) Traffic is closed in positive direction and open in negative direction. (3) Traffic is closed in negative direction and open in positive direction. (4) Traffic is closed in both directions.[13]

Validity Period is the time domain or time limits to access a road [13]. Jalan Datuk Keramat is the example of road with validity period attribute. From 7.00a.m until 9a.m, road in front of train station PUTRA Datuk Keramat has been changed from two ways into one way.

Vehicle Type is the type of vehicles for the information in an associated sub-attribute [13]. Vehicle types describe type of vehicle that allowed using particular road due to vehicle height and weight on the road, bridge and tunnel. This attribute normally applied to heavy vehicle like lorry, trailer and bus.

III. CONCLUSIONS

Even though research area is limited to Klang Valley road network only but it should be enough to investigate classifications of prohibited manoeuvre in Malaysia. It is complex, congest, but modern. Development of CNS

start from data collection until quality checking require skilled surveyor and draught person. This is to avoid mistake to happen during both process. Mistake created by either of these two people will put life of others in dangers. Current quality checking practices that have too many manual operations need to be revised since volume of data for navigational digital maps keeps piling up. It is recommended for local map provider to start implement fully automation quality checking to avoid human error.

The documentation of prohibited manoeuvre classification is part of the initiatives to produce a document similar to geographical data format (GDF) that suits Malaysia road network. Current GDF that become reference for the local map provider is based on European road network model. Though GDF document still the main reference but when developing a quality checking and conversion tools, it is more convenience and safe if the template are based on Malaysia own road network. The important of remodeling standard GDF conversion is to ensure 100% automation in quality checking tools to eliminate error that might be introduced by human operator during conversion process. Hopefully, with Malaysia own template for GDF conversion, number of accident cause by wring guidance by CNS can be overcome.

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