TRANSPORT INFRASTRUCTURE DEVELOPMENT MODELLING FOR DISPERSED CITIES

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Abstract- Over the years there have been many Transport Infrastructure models developed and implemented, however these models are quite generic and do not totally satisfy the ever continuously changing Transport Infrastructure Environment for dispersed cities. This paper will propose a robust and sequential Transport Infrastructure Development Modelling (TIDM) mechanism especially for dispersed cities. Furthermore, this proposed TIDM utilises the Comprehensive Mobility Plans (CMP) technique together with, Traffic Analysis (collection and analysis of the existing urban transport environment), Transportation planning (including urban use and strategy) and various Implementation programs. In addition, this paper considers more technical Traffic ngineering concepts such as Volume to Capacity ratio. Moreover, the proposed TIDM will be implemented on Melbourne (Australia) as a preliminary case study and the initial results will be reviewed and discussed. The conclusion of this paper, will consist of the preliminary findings and outcome of the TIDM, will then be critiqued and discussed.

Keywords-Transport Infrastructure Development Modelling (TIDM); Traffic Analysis, Transportation lanning and Implementation; Traffic Engineering, Melbourne city (as a case study); and Robust and equential Modelling.

I. INTRODUCTION

Transport Infrastructure Development Modelling (TIDM) for dispersed Cities requires careful Transportation Planning and Implementation which involves the evaluation, assessment, design and assembling of transport facilities such as Roads, Major arterials, public Transport etc. Furthermore, as part of Transport Infrastructure Development Modelling (TIDM) mechanism for dispersed Cities, fastidious and rational Transportation Planning and Implementation of specific goals and objectives is required which will identify potential problems, generates and evaluates alternatives, and develops various technical plans. Generally, generic models for such purpose include Transit Oriented Development, which alternatively utilize Comprehensive Mobility Plans and other similar tools to design and deliver various Transportation Infrastructure planning and implementation methodologies [13]. Moreover, these models also utilize various scenarios such as Future Transport Network, Future Land use to improve the overall quality of the proposed model's output. More importantly, various stage by stage trail runs are also conducted to observe any improvements in the overall traffic congestion and/or Transportation systems.

Transport congestion is a growing concern with many global cities in particular dispersed cities, including Melbourne, and the demands on Transport Infrastructure services are increased by the rising expectations from the growing population which in turn, places greater stress on these cities and their services. As such this requires the ability to design and implement ffective Transport Infrastructure Development Modelling (TIDM) for dispersed Cities, which Melbourne can be categorised as. Transport Infrastructure is an integral part of Australian economy, and essential part of this TIDM is the creation of omprehensive Mobility Plans which includes the utilisation of Transport Demand Model (TDM); Development of ransport Model (DTM), together with Transport and land use considerations [13]. Although the focus of Transport nfrastructure is mainly within areas of roads, public transport such as trains, trams and buses it also needs to encompass the urban geography and development [14]. In addition, the proposed Transport Infrastructure Development Modelling (TIDM) will utilise a Robust and Sequential Modelling mechanism to ensure it can be utilised for a specific Transport Infrastructure area with only some minor modification and adjustment. However this methodology requires the involvement of model trial and initiation which involves specific Transportation classification suchas road networks, public transport etc. as an input. These inputs are necessary as a part of major city connection with the rural areas and towns, which are sometimes, referred to as Transport Infrastructure Distribution Methodologies.

II. TRANSPORT INFRASTRUCTURE DISTRIBUTION METHODOLOGIES

The main focus of any Transport Infrastructure Distribution Methodology is to connect the main business centres such as manufacturing, industrial areas together [15]. These distribution and connection strategies must be well planned and based on actual analysed data to ensure not only providing more Transport program implementation focus where it is required, but also to present an opportunity for any future Transport Infrastructure upgrades. As cities are ever expanding, the areas within the dispersed Cities are starting to merge and creating more Transportation Planning and Implementation predicament, hence the importance of considering

'Future Land Use' scenarios. In addition to consider all of these issues, careful deliberation needs to be measured and undertaken for the regional areas which serve as an important economic service [11]. This in turn requires the availability of relative and affordable resources including land to support these ongoing Transport Infrastructure Distribution methodologies. On the other hand, factors such as the relative, affordable and available land present opportunities for the consolidation and future growth of the transport industry within the most dispread cities.There are many competitive factors currently impacting the transport sector, which requires careful considerations such as; the high capital cost of design and construction, changes to the legislations, and the impact of the increase in demand and usage of Transport Infrastructure [10]. Other areas which require careful consideration during Transport Infrastructure Distribution Methodology initiation include [10]:

• Transport Infrastructure Planning and Development. Transport Infrastructure Planning and Development involves the various aspects of land use planning, building construction and land subdivision which are administered by governments at all levels. The aim is to achieve high quality and sustainable development outcomes in the urban and rural areas, and taking into account important issues such as preservation of the physical environment as a part of broader Transport Infrastructure Planning and Development assessment.

• Transport Infrastructure Economic Development. The main aim of major cities role as an increasingly dominant regional service centres are underpinned by a strong regional economy based in manufacturing, logistics, wholesale trades etc. Thus indicating the importance of regional areas, since their economy is usually dynamic and vibrant, making it well placed to cope with future economical structural changes resulting from the needs of an ever-changing demographic profile. As a part of an overall economic development, regional economic development program for Transport Infrastructure needs to be created and encompass into any Transport Infrastructure Development Modelling (TIDM). The proposed model TIDM, in an economic sense (as well as overall methodology) is robust, sequential and more adaptive, and considers more parameters (such as Engineering requirements and CMP) than the other existing generic models.

• Transport Infrastructure Engineering Requirements. These requirements provide fundamental tools of evaluation of Transport Infrastructure and their performances. These are four fundamental aspects "The Four Core Elements" which need to be built-in into the Transport Infrastructure Development Modelling (TIDM), and will be covered in detail later.In addition to all of the above areas, a precise Comprehensive Mobility Plans also needs to be established as a part of Transport Infrastructure Development Modelling (TIDM) process.

2.1 Comprehensive Mobility Plans

The overall methodology for a transport demand model comprises of two major steps [7]: i) Developing a Base Year Transport Demand Model, and ii) Developing a Future Transport Demand Model. The following figure illustrates the combination of these two steps.

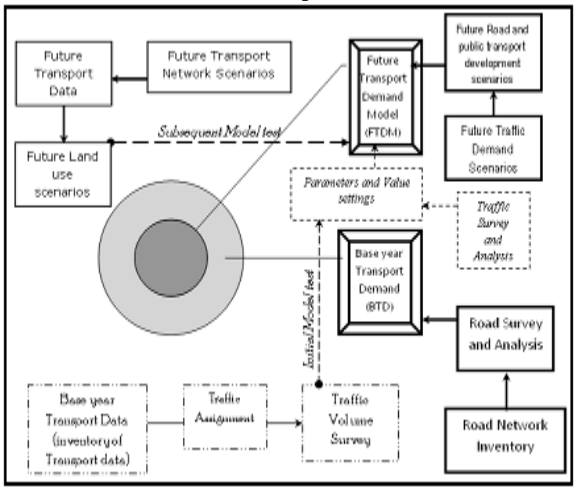


Figure 1, Comprehensive Mobility Plans (CMP) [7].

As it can be noticed, there are two central areas:
a) Future Transport Demand Model (FTDM). This is the inner area (base), which is influenced by two sections:
i. Future Road and public transport development scenarios, to observe the full potential of land subdivision and use (analysis) via the various future land use scenarios such as buy-back strategies for Transportation Infrastructure upgrades. At this stage, subsequent model test can be carried out to align the parameters and values with any findings and outcomes from the 'future land use scenarios' stage. Future Road and public transport development scenarios section, in turn is influenced by Future traffic demand scenarios.

ii. Future traffic demand scenarios, to recognize the initial capacity of the roads and/or public transport. This is aided by the parameter setting which is required for any modelling such as Traffic Value Settings etc. Furthermore, the FTDM requires the analysis of the public transport data which will then create the additional parameters where necessary. The parameters and value settings are also the result of the traffic volume survey and analysis which is the result of the initial transportation data inventory. It is eminent to note that, at the conclusion of the 'traffic volume survey' stage, the initial model test can commence to observe any discrepancies at its early stage.

b) Base year Transport Demand (BTD). This is the outer area and it is less complex then the inner area, and it simply proceeds from Road Network Inventory (consists of road classifications and usage) to Road Survey Analysis (including peak and off-peak level and usage), which form an annual transport demand progression.

Overall, creating a precise Comprehensive Mobility Plan (CMP) is a significant task within the development of the Transport Infrastructure Development Modelling (TIDM). Moreover, "the base-year model" could be developed based on the surveys conducted and it should be calibrated into the Transport Infrastructure Development Modelling (TIDM). Furthermore, the base-year model for the target year (ie year x) should then be developed, with the future transport network and land use scenarios specifications. In addition of CMP, fundamental part of the TIDM is the engineering aspects.

III. ENGINEERING FEATURES OF TIDM

As previously discussed, the Engineering features of TIDM provide fundamental tools of evaluation of Transport Infrastructure Systems and their performances. These are fundamental aspects (The Four Core Elements) of Infrastructure Engineering requirements which need to be incorporated into the Transport Infrastructure Development Modelling (TIDM). These four core elements include [13]:-

1. Infrastructure (Transport) Asset Rehabilitation and Renewal. This element includes the assessment and renewal of all assets such as bridges, roads, and Transportation structures. As a part of Infrastructure Asset rehabilitation and renewal this first core element initially includes "Evaluating assetcondition and performance". This is necessary to [17]: Activate asset maintenance (condition-based or predictive maintenance); Identify assets requiring rehabilitation and replacement in the short, medium and the long term; and Present raw data for creating asset deterioration models. Once an extensive and detail asset condition and performance evaluation has been applied, the second phase "developing an asset renewal strategy" commences. This involves the identification of future asset renewal costs and addressing the prioritisation and funding of the typical liabilities [21].

2. Structural Performance and Operation. This element includes, damage threshold for transportation structures, erformance of structures to extreme events such as act of GOD including earthquakes, and/or strategies for the development of the next generation of construction standards (progressive Quality Management). This area also includes the management and upervision of the Transport Infrastructure Assets via theories and techniques such as Structure Performance Analysis [12]. The Structure Performance Analysis methods are alternatives to avoid the computational complexity problem associated with other techniques such as Discrete Event Simulation. In this process even if a finished conceptual and technical ramework is not yet obtainable, significant advantages have been obtained not only from performance position, but also from design correctness analysis stages. In designing any analytical testing techniques the following procedures need to be evaluated [22, 24]: Do the designed test methods describe the determination of all the structural performance of all substructure or superstructure components; The test methods need to be intended specifically for evaluating the structural performance associated with the specific test specimen; and The testing procedures need to be based on the relevant standard and clearly shown various loading dimensions such as dead, live, wind loads etc.

3. Sustainable and Tangible Materials. This element includes the thorough investigation of utilised materials such as, ecycled concrete; diverse grades of timber, metal selection such as iron vs steel vs aluminium, and aggregates such as asphalt mixtures selection. This area also includes the Quality Control of the Materials used within the Transport Infrastructure Assets. In addition, Sustainable and Tangible Materials approach could include developing new materials processes to enhance sustainability by decreasing pollution, emissions, energy consumption and improving eco-efficiency of materials processing, and modular construction and advanced materials. For example, sustainable technologies areas such as utilisation of waste plastics in iron-making and steelmaking technologies could be utilised to produce test samples and prototypes (design, manufacture, testing, and analysis) to be utilised for Transportation Infrastructure. Some of these Sustainable and Tangible Materials elements have already been applied in real life projects in association with industry and the public sector, to develop construction products that are based predominantly on industrial waste materials and utilising a cement free process. Other similar research project could include: Repair material formulations and solutions for Transport Infrastructure such as road and bridge structures; and Sustainable and durable construction materials developed from einforced earth using various reinforcement techniques.

4. Emerging Robust Technologies and Innovative Tools. This element includes the use of software such as RIVA (Real-time Asset Valuation Analysis) and/or Sensor applications in Transport Infrastructure monitoring. Other Transport Asset anagement Systems such as: Mapinfo's Confirm, SMEC (Pavement Management System), XPSWMM

(Stormwater Drainage modellings/design softwares), and GIS systems such as Geomedia's WEBMAP could also be included in this element. Moreover, this element includes the research, recommendation and implementation of the newly created and derived technologies (in terms of expertise, equipment and machinery) within the Transport Infrastructure Assets [23]. The Emerging Robust Technologies and Innovative Tools will be needed for Transport Infrastructure Optimisation in this new high technological era to meet the public's demand for high-quality and convenient transportation requirements. The successful implementation of these practices will encourage and enable responsible transportation authorities to utilise the new technologies appropriately to complete the works quickly with the minimum disruption to traffic, while incorporating quality that will ensure long-lasting, low-maintenance facilities, thus creating a win-win situation for all involved.

Figure 2, provides the schematic for The Four Core Elements and their inter-relationship.

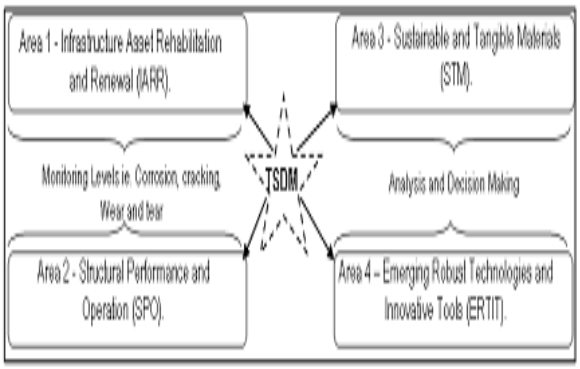


Figure 2, Schematic of the TIDM four core elements [13].

As it can be noticed, although the four core elements are reactive to one and another, they have separate and specific monitoring mechanisms. Areas 1 and 2 are governed by Condition Monitoring Levels and Strategies for problems such as corrosion, cracking, wear and tear conditions of the Transport Infrastructure Assets. While Areas 3 and 4 are controlled by Analysis and Decision Making processes.

Condition Monitoring Levels and Strategies include: evaluating asset condition; developing an asset renewal strategy and performance mechanism; and transportation's structure performance analysis & assessment techniques. The Analysis and Decision Making processes include: decreasing pollution processes; emission control procedures; energy consumption and improving eco-efficiency of materials processing; together with the implementation of the newly created and derived technologies. These two administrative techniques are usually not only based on Local, State and Federal transportation guidelines and polices, but also by each specific responsible authority. These four core elements are the integral components of the TIDM. Next section discusses the proposed TIDM for dispersed cities.

IV. TRANSPORT INFRASTRUCTURE DEVELOPMENT MODELLING (TIDM) FOR DISPERSED CITIES

As previously discussed, the proposed TIDM requires the integration of the CMP and the Four Core Elements to ensure it is Robust and Sequential. The TIDM is shown in below figure.

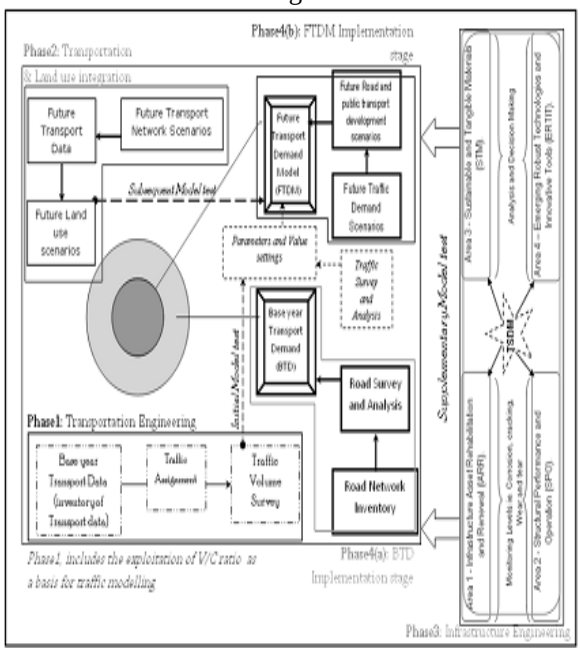


Figure 3, Transport Infrastructure Development Modelling (TIDM) for dispersed Cities

As it can be noticed, the proposed TIDM integrates both CMP and the Four Core Elements (which were discussed in detail previously), and combines their output into the model. To design robustly and sequentially methodology into the model, there are four principal phases which are interlinked:-

• Phase 1: Transportation Engineering. This phase requires the use of Traffic Engineering Technique: Volume to Capacity ratio as it core principal. Approximately most major arterial roads and networks have 0.7 as their V/C ratio. Any ratio over 0.7 indicates some predicted traffic congestion. It isimportant to keep V/C ratio below this average, although during the peak hours this average may move beyond 0.7, however the mean average needs to comfortably be under 0.7 V/C ratio.

• Phase 2: Transportation and Land use integration. In this phase, it is important to consider any road reserve or overlays in place for future road upgrade and expansion. As a part of the future road upgrade and expansion planning, buy-back rinciples (which the commercial/industrial/residential land is

purchased for the purpose of transportation upgrades) may also be included. The buy-back principles may include purchase of the land for other transportation upgrades, ie ew/upgrade rail network, etc.

• Phase 3: Infrastructure Engineering. This phase has been previously discussed in detail and it initiates the hub of the proposed TIDM. This is the phase in which the robust and sequential methodology is centrally formed.

• Phase 4: Transportation Implementation. Since this is the final phase, it requires the integration of the previous phases which is divided into two major areas to represent the two central areas of CMP. For both the FTDM and BTD, the relevant processes and progressions need to be included and incorporated in the model. This ensures that the model is complete and there are logical and theoretical gaps.

As it can be noticed the above TIDM is a Robust and Sequential which is proposed for dispersed cities, such as Melbourne. Although this model requires careful implementation, and the results need to be meticulously and mathematically analysed; it is important that a comprehensive trial test be conducted and the results be analysed, which will then validate the model. However, as an initial simplistic test, Melbourne will be used as a basic trial and methodology test and to observe any positive outcome of the model, therefore to validate the overall theoretical concepts of the model.

4.1 Melbourne - preliminary case study

As a case study, Melbourne has been selected to trial the proposed TIDM and to observe any primary results and outcomes. It is important to note that due to time constraint an in-depth and detailed mathematical study and analysis was not carried out. However the proposed model will be tested more rigorously & mathematically and the findings will be analysed in detail, after this publication. Prior to the initial testing, it is important to first evaluate the existing problems within the Melbourne Transport Infrastructure. Due to decades of population and planning growth, the public transport patronage in Melbourne is rising in a rapid pace. This has created significant challenge for the Victorian state government as well as the local governments. Crowding on trains (as well as on trams and some bus routes) has resulted, and the impact of just one cancelled service (in particular train services) is severe. Based on many recent surveys (between 2010 to 2013) both at the local and state wide levels, it can be determined that trains, trams and even some buses routes, services are poor; infrequent, particularly at weekends, and there is no competition for the motor car as a pollution reduction strategy, despite increasing traffic congestion, impact from petrol prices and concern about emissions.

In their 2013 – 2014 state budget the Victorian state government has proposed significant upgrades to the rail infrastructure to relieve peak-hour crowding, but ignoring the need for more services outside peak hour, and to areas of Melbourne not serviced by the train network [2]. In addition the state government is also investing considerable time and money into planning for future road construction such as East West Link, and therefore entrenching car-dependence in the middle and outer suburbs [2]. Moreover, Victoria and in particular Melbourne (as a city) in terms of Transport Infrastructure falls well short of some of the more enhanced cities around the world, including London, Berlin etc. These cities and others alike, have significantly better public transport, to give everyone the option of travelling without a car, which is also another issue with pollution to consider. Furthermore, Melbourne's freeways consistently need to be upgraded and this not only creates more nuisance for the Victorian state government but also the commuters. Victorian state governments argues that at the time of the planning there were not sufficient budget available to plan ahead, and if at the time the freeways were design and build with too much planning ahead (i.e. 6 lanes highways (in each direction), Melbourne would of ended up similar to Detroit and Los Angeles where there are vast amount of freeway routes with little or minimum usage. Furthermore, the Victorian state government argues that they have taken the mean approach and have tried to ensure continuous design and construction of Roads and other Transportation Infrastructure in line with the increase demand and requirements, and this is on-going effort.

However, by following this path, the Melbournian seem to be involved via more pollution, congestion and unacceptable road trauma. Although there is sound public transport Infrastructure available, it is poorly managed and utilised. Time and time, arious surveys conducted have demonstrated the dissatisfaction by the community of the Melbourne Transportation nfrastructure, including the public transport due to lack of foresight in transportation planning and implementation trategies. Specifically, these general dissatisfaction were based on waiting period (some areas have services only every half-hour), pricing (according to ABS [4] Melbourne has the most expensive public transport fare in Australia), and Safety (although generally of a sound standard but more improvement are required especially if outskirts of Melbourne, especially blind spots at some rural road intersections). It is these Transportation Infrastructure issues which put Melbourne in a position now to have public transport that is unsustainable and unaffordable for both tax payers and passengers, and; a Transportation system which will not only continue to serve a fraction of the population, but also needs to constantly be upgraded. Moreover, the Victorian state government argues that their proposed Transportation Infrastructure planning

and implementation strategies are clearly based on the urban growth and related zoning requirements [2]. Figure 4 provides the Melbourne urban growth zoning as of September 2012. In addition to the 2012 Melbourne Urban Growth Zoning, the figure 5 provides the Major Transport Infrastructure activities within the Melbourne.

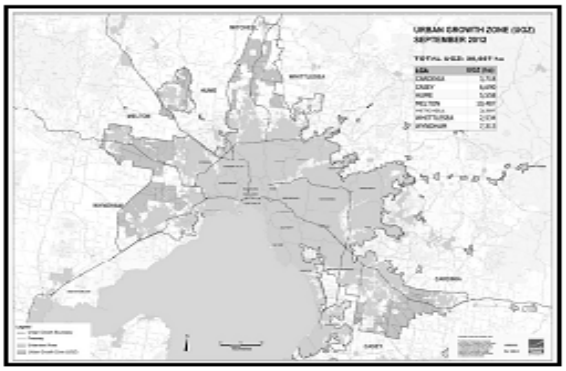


Figure 4, Melbourne 2012 Urban Growth Zoning, [1, 2] F

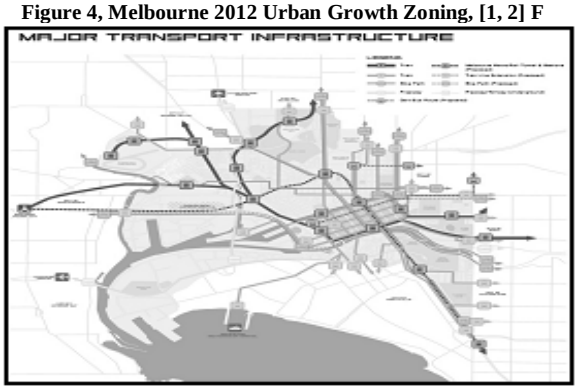


Figure 5, the Major Transport Infrastructure within the Melbourne [1, 2]

As it can be noticed, the Major Transport Infrastructure within the Melbourne clearly follows the proposed urban growth zoning. Although this is the first law of sound Transport Infrastructure planning and implementation strategies [20] other considerations needs be measured to ensure that Transport Infrastructure System is efficient and sustainable. Before the proposed TIDM can be applied, first some general recommendations need to be provided to Melbourne's Transport Infrastructure issues. Although the above figure shows the Melbourne growth areas, this needs to be correlated in the bigger picture of the linking the outskirts of the Melbourne, to the city hub. This requires advancement is three key areas, improved services, integrated public transport including upgrading and rehabilitation of existing transports assets such as train stations, and design and construction of new rail lines and major arterial roads. Currently there are minimum services delivery measures in place to ensure that the public transport services are meeting the benchmarks (i.e. 92% efficiency rate for the Melbourne Trains). However significant improved Transport Infrastructure Integration is required including new rail lines and related transportation upgrades. Although currently some upgrade and new rail lines are being constructed, much more upgrades are required to ensure that Melbourne and its surroundings areas have sufficient transport Infrastructure.

4.1.1 The use of model to assist with Melbourne Transport Infrastructure

The proposed Transport Infrastructure Development Modelling (TIDM) in this paper will provide significant foundation with the overall transportation systems. The application of TIDM in methodology for Melbourne includes:

• Phase 1: Transportation Engineering. All major traffic modelling for the major arterial roads within Melbourne have carried out vigorous V/C ratio analysis. Their results via different reports indicate the mean V/C ratio is within the 0.7 tolerance value. However, specifically during at the peak-hours times, the 0.7 value was over reached and at times the v/c ratio even surpassed the 1.0 value. Therefore, the Victorian State government, proposed many dissimilar and on-going upgrades to these transportation Infrastructure, which most are commencing with some at their final stage.

• Phase 2: Transportation and Land use integration. Just recently Victorian State Government has started buy-back of some lands for the proposed East West Link project. The next few photos represent the overall planning schemes for the East West Link project.



Figure 6, East West Link Project Connection Overview, [3, 19]

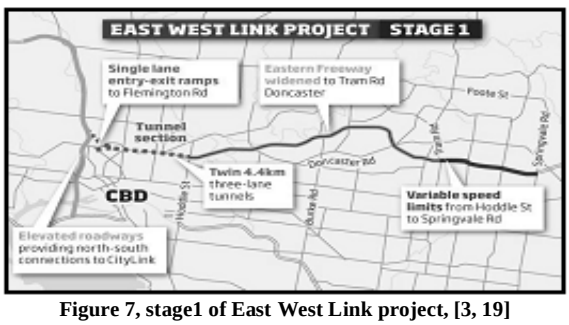


Figure 7, stage1 of East West Link project, [3, 19]

According to Victorian State government, the East West Link is an 18 kilometre cross-city road connection extending across Melbourne from the Eastern Freeway to the Western Ring Road (figure 6). Planning is currently underway for the first stage of the East West Link, a six kilometre roadway connecting the Eastern Freeway with CityLink. The

Victorian Government has committed to building the East West Link Stage 1 (figure 7), between the Eastern Freeway and CityLink. The formal planning study that we are currently carrying out also includes a connection from CityLink to the Port of Melbourne area. In addition, while currently there is not any commitment to build the connection to the Port; Linking Melbourne Authority will continue to explore opportunities for procuring this section of the project and potential timeframes.

• Phase 3: Infrastructure Engineering. Although there are specific regulations and codes for each specific areas of this phase, area 1: IARR in particular is quite poor. Furthermore, although at the Macro level it seems that the Victorian state overnment is capable, at the Micro level there are major gaps with the overall methodology and service delivery of area 1 including arious renewable techniques and procedures. Area 1 needs to be closely linked with area 2, to ensure that the overall methodology and service delivery are consistent and are in-line with the existing Transportation Infrastructure planning and implementation requirements. It is here that Melbourne as a dispersed city, significantly lacks sustainability and hence this should be the starting point to mend the Melbourne's Transportation Infrastructure issues.

• Phase 4: Transportation Implementation. The Victorian state government, in their proposed 2014-2015 budget, has proposed some major upgrades to existing Transportation sector such as further study and investigations into establishing a new rail line, including Doncaster line (which is an outer eastern suburb of Melbourne). Some of these Transportation Infrastructure upgrades require federal assistance due to their significant capital requirements. All of the Melbourne's transportation system's processes and progressions need to be included in this phase, which needs to be on-going and consistent with any future Transportation Infrastructure planning and implementation programs.

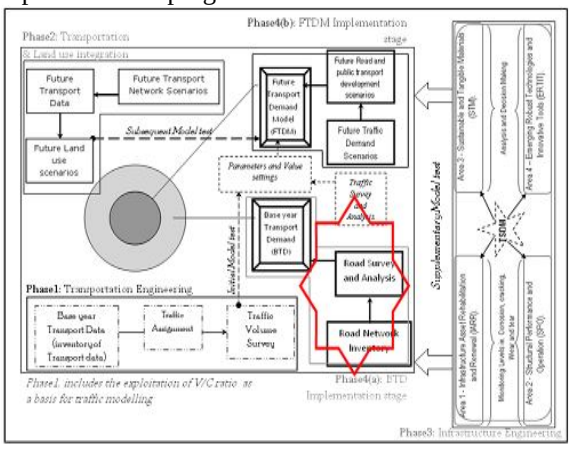


Figure 9, TIDM and Melbourne

Overall, phase 3 should be as the starting point to rectify Melbourne's Transport Infrastructure issues. Although this may not totally rectify Melbourne's issues, it will defiantly validate the overall methodology of the proposed TIDM.

CONCLUSION

Transport congestion is a growing concern with many global cities including Melbourne, and the demands on Transport Infrastructure services are increased by the rising expectations from the growing population which in turn, places stress on these cities and their services. Transport Infrastructure Development Modelling (TIDM), for dispersed Cities requires careful Transportation Planning and Implementation which involves the evaluation, assessment, design and assembling of transport facilities. This paper roposed a robust and sequential Transport infrastructure Development Modelling (TIDM), and ncluded Melbourne (Australia) as a preliminary case study and to validate TIDM's overall methodology. The proposed TIDM utilised the CMP technique together with various Transportation Infrastructure planning and implementation strategies and techniques. In doing so, this paper considered more technical Traffic Engineering concepts such as V/C ratio, together with Transport Infrastructure Engineering theories and concepts which were linked with CMP. Finally, upon its preliminary implementation on Melbourne as an introductory case study, the primary results were reviewed and discussed. As a pilot case study application indicted, the Infrastructure Engineering phase with the TIDM is where Melbourne lack significantly and thus requires significant advancements. It is important to note that the proposed TIDM is in its early stage of development and initiation and further work is required to test, implement and analysis the outcome of TIDM carefully.

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