A report of the 27th Prof. Chin Fung Kee Memorial Lecture delivered by Ir. Dr Ooi Lean Hock on 18 November 2017

Underground MRT in Kuala Lumpur: The Inevitable Urban Transit Solution

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The spirit of Tan Sri Prof. Chin Fung Kee lives on

Tan Sri Prof. Chin Fung Kee's name invokes the memory of a person who embodied a value system very much respected by Malaysian engineers. It is synonymous with the following values:

- Dedication to one's chosen career.
- Commitment to the assigned tasks in service of men.
- Belief in a meritocracy system.

Thus, it is no wonder that Tan Sri Prof. Chin is remembered as the country's foremost engineering educator and an outstanding practising engineer. The 27th Annual Prof. Chin Memorial Lecture is a fitting occasion that recognised his contributions to our engineering industry and nation-building. See *JURUTERA*, November 2015, pages 25-28.

The speaker Ir. Dr Ooi Lean Hock

Ir. Dr Ooi Lean Hock graduated with a PhD from University of Sydney, Australia. He worked as a geotechnical consultant and a specialist contractor before joining MMC-GAMUDA in the SMART Tunnel project. He is currently the lead geotechnical engineer in the Design and Technical Department of MMC-GAMUDA KVMRT (T) Sdn. Bhd. for the second line of Klang Valley Mass Rapid Transit namely the Sg. Buloh Serdang PutraJaya (SSP) line. He has extensive experience in ground treatment works, more recently in deep excavation and tunnelling works. He also has a keen interest in geotechnical instrumentation and testing. He has been involved in many interesting infrastructural projects such as railways, runways, highways, tunnels and hydropower both locally and abroad.

Note:
The title "Underground MRT in Kuala Lumpur: The Inevitable Urban Transit Solution" is taken from Ir. Dr Ooi Lean Hock's lecture. In this report, the more suitable title is "A Liveable City: Enabled by Underground connectivities".

Traffic congestion is defined as the result of too many cars on roads which have reached the maximum vehicle capacity. As any office worker in Kuala Lumpur will testify, traffic congestion is the cause of much misery as a person will, on average, spend 34% extra travel time in the morning rush hour to get to the office; he will need 56% extra travel time and another 80% extra travel time in the evening rush hour (1). Computing the total loss of productive time, this translates to a whopping extra 41 minutes travel time per day to him or an extra 158 hours travel time per year, according to the same report.

In the *World Bank* report survey conducted in 2014, Jensen and Reimann (2015) found that only 17% of Kuala Lumpur commuters used public transport. This figure compared unfavorably with 62% in Singapore, and 89% in Hong Kong [2]. In all, the report found that Greater Kuala Lumpur commuters wasted 250 million hours a year in traffic jams. In economic terms, this was a loss of RM54 million a day as a result of unproductive hours.

However, the main culprit of Kuala Lumpur's traffic congestion could be the *laissez faire* manner in which the city authority managed urban transportation planning. *Akmal S. Abdelfatah et al., (2015)* noted that private car ownership increased from 5.5 million in 2003 to over 10 million in 2012, an exponential 81.8% growth in just 9 years [3].

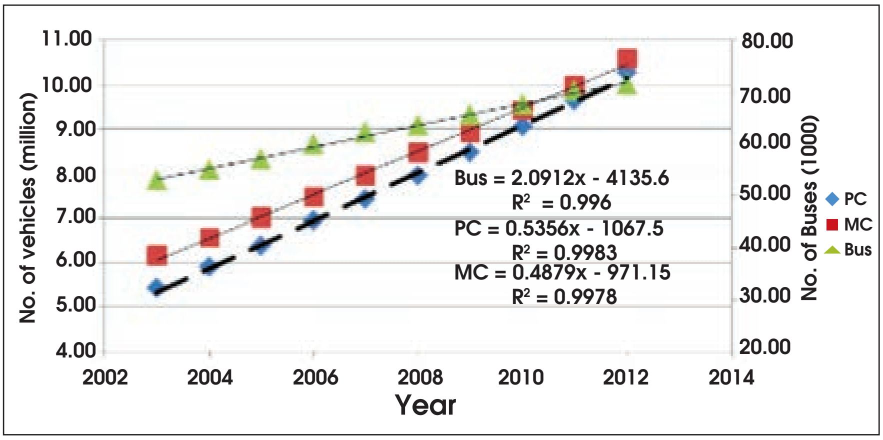

Figure 1: Passenger car, motorcycle and bus registration
Source: Akmal S Abdelfatah et al., (2015)

See Figure 1. Put differently, the increase of private cars per year was 500,000, compared to a paltry increase of just 2,000 buses per year.

So the menace of traffic congestion is well understood. What is not is the magnitude of the need to change our behaviour with respect to overcoming the traffic congestion in Kuala Lumpur. As an example, after Uber commissioned Boston Consulting Group (BCG) on how to mitigate traffic congestion in 2017, it discovered that the current 5.8 million cars in Kuala Lumpur were way beyond the carrying capacity of the city roads; 40% of the cars must be replaced by alternative transport options [4].

In this short article, instead of reporting Ir. Dr Ooi Lean Hock's lecture verbatim (it will be reported in full in *IEM Journal* later), we seek out the motivations behind the construction of the MRT1 and MRT2 Lines. We raise three questions: First, what is considered a liveable city (assuming that the traffic congestion is brought under control)? Second, how would urban transit solve the traffic congestion woes? Third, why do we go underground in Kuala Lumpur, and what are the major geological challenges of deep excavation and tunnelling related to mitigating traffic congestion — as we learnt from Ir. Dr Ooi's lecture?

LIVEABLE CITY: GREATER KUALA LUMPUR'S ASPIRATION

In his lecture delivered on 18 November, 2017, Ir. Dr Ooi pointed out that an integrated public transportation system was key to achieving 50% public transport ridership by 2020, without which the ideal state of a liveable Greater Kuala Lumpur would remain a distant dream. In this section, we shall focus on two issues: The concept of a "liveable city" and the emergence of an acceptable framework used to measure the level of a smart city.

Concept of Liveable City: The concept of liveability first appeared in the 1950s. In the literature review, an accepted definition of a liveable city should include 6 broad principles:

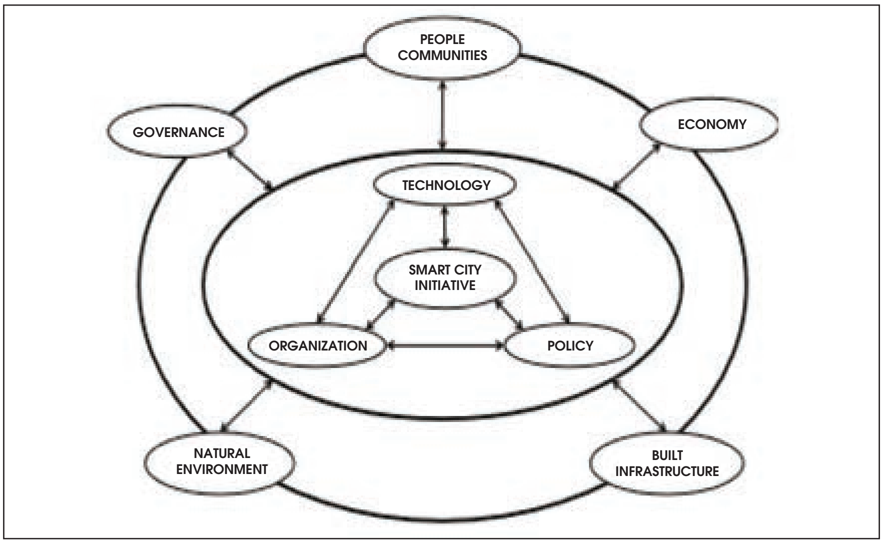

Figure 2: Smart city initiatives framework.
Source: Chourabi, Nam and Walker (2012)

Provide more transportation choices, promote equitable and affordable housing, enhance economic competitiveness, support existing communities, coordinate and leverage federal policies and investment as well as value communities and neighbourhoods [5]. By and large, transportation is the most important in determining whether a city is liveable. The next crucial principles are the wellbeing of the communities from housing to economy. As we shall see later, many of these principles are similar to frameworks used to categorise smart cities except in ICT (information communications technology) provision.

Acceptable framework for assessing a smart city. Chourabi, Nam and Walker (2012) proposed a framework for a smart city after exhaustive studies [6]. See Figure 2. In the diagram, smart city initiatives are driven by people, policy and ICT. The emphasis appears to be on ICT. However, what appears to be missing is urban transit, or for that matter, transportation planning.

A refinement on this model (as in Figure 2) was made by Albino, Berardi and Dougelico (2015) who cited research findings by *Lombardi et al.,* (2012) and identified 5 components suitable for the study of a smart city: Smart economy, smart people, smart government, smart environment and smart living. One additional component was added: Smart mobility. Therefore, from this point onwards, mobility is also key in the definition of a smart city [7]. The said framework recognises the multi-faceted nature of a smart city to include the quality of people, communities and ICT provision.

Monzon (2015) created a method of assessment to compare and contrast two sets of cities: The well-developed North Mediterranean cities and the developing South and East Mediterranean cities [8]. The researcher accepted the framework of Albino, Berardi and Dougelico (2015), but further refined it by operationalising the model in connecting both city sets through the variables as shown in Figure 3. In addition, in this model, infrastructure was identified as the central piece, technology the enabler, and through integration of infrastructure and technology, an assessment of a smart city was made possible.

If mobility is paramount to the success of a smart city, urban rapid transit should then be seen as a means to alleviate traffic congestion in the Greater Kuala Lumpur, as explained in the next section.

URBAN RAPID TRANSIT

In this section our task is to collect empirical evidence from the relevant literature: First, the car-based system as applied to the Greater Kuala Lumpur, and second, the expected outcome in adopting a transit-based system.

Evidence of car-based system. There is a rich source of literature leading up to the current car-based system. In particular, Barter (2000, 2004) labelled Kuala Lumpur Metropolitan Area (KLMA) as moderately traffic saturated compared to other Asian cities such as Bangkok and Manila, but moving close to car-dependence [9, 10]. He attributed this condition to institutional arrangements that encouraged car-ownership.

In Table 1, if we focus on comparing the column HIA (higher-income Asian cities such as Hong Kong and Singapore) with the column Klang Valley, the income disparity between the two is very great (US$34,797 and

Table1: Transport system and land use characteristics in the Klang Valley compared with middle-income and high-income groupings of cities, circa 1995

		USA	ANZ	CAN	WEU	HIA	MIA	MIO	Klang Valley
Metropolitan gross domestic product per capita	USD	31,386	19,775	20,825	32,077	34,797	9,776	6,625	6,991
Passenger cars per 1000 persons		587.1	575.4	529.6	413.7	217.3	198.3	265.1	208.7
Motorcycles per 1000 persons		13.1	13.4	9.5	32.0	65.8	154.0	14.7	174.5
Passenger car passenger km per capita	Pass. km/cap.	18,155	11,387	8,645	6,202	3,724	3,517	4,133	4,345
Motorcycle passenger km per capita	Pass. km/cap.	45	81	21	119	100	1,165	78	1,365
Length of expressway per 1000 persons	m/1000 cap.	156	129	122	82	22	27	43	68
Parking spaces per 1000 CBD jobs		555	505	390	261	121	164	374	298
Motorised passenger km on public transport	%	2.9	7.5	9.8	19.0	50.3	26.9	36.6	10.8
Public transport seat km of service per capita	seat km/cap.	1,557	3,628	2,290	4,213	5,535	2,734	3,283	1,331
Overall average speed of public transport	km/h	27.4	32.7	25.1	25.7	33.2	16.4	24.8	18.5
Average road network speed	km/h	49.3	44.2	44.5	32.9	31.3	20.9	35.9	28.1
Ratio of public versus private transport speeds		0.58	0.75	0.57	0.79	1.08	0.78	0.70	0.66
Total emissions per urban hectare (CO, SO_2, VHC, NOx)	kg/ha	3,563	2,749	4,588	5,304	3,894	12,952	7,236	7,889
Urban density	persons/ha	15	15	26	55	134	164	54	58

Source: Kenworthy and Laube (2001).
The cities included in these groupings are as follows:
Western and Southern Europe (WEU): Munich, Frankfurt, Zurich, Geneva, Düsseldorf, Bern, Lyon, Paris, Stuttgart, Vienna, Oslo, Hamburg, Copenhagen, Stockholm, Ruhr, Nantes, Graz, Marseilles, Helsinki, Amsterdam, Brussels, Bologna, Rome, Milan, Berlin, London, Barcelona, Madrid, Glasgow, Manchester, Newcastle, Athens;
United States of America (USA): San Francisco, Washington, New York, Denver, Chicago, Atlanta, Houston, Los Angeles, Phoenix, San Diego;
Canada (CAN): Vancouver, Calgary, Toronto, Ottawa, Montreal;
Australia and New Zealand (ANZ): Sydney, Perth, Melbourne, Wellington, Brisbane;
High Income Asia (HIA): Tokyo, Osaka, Sapporo, Hong Kong, Singapore;
Middle-Income Asia (MIA): Taipei, Seoul, Klang Valley (Kuala Lumpur), Bangkok;
Middle-Income Other (MIO): Tel Aviv, Prague, Curitiba, Riyadh, Budapest, Sao Paulo, Johannesburg, Cape Town, Kraków
Note: In the case of the Klang Valley, most of these data refer to 1997. CBD = central business district

Source: P. A. Barter (2004)

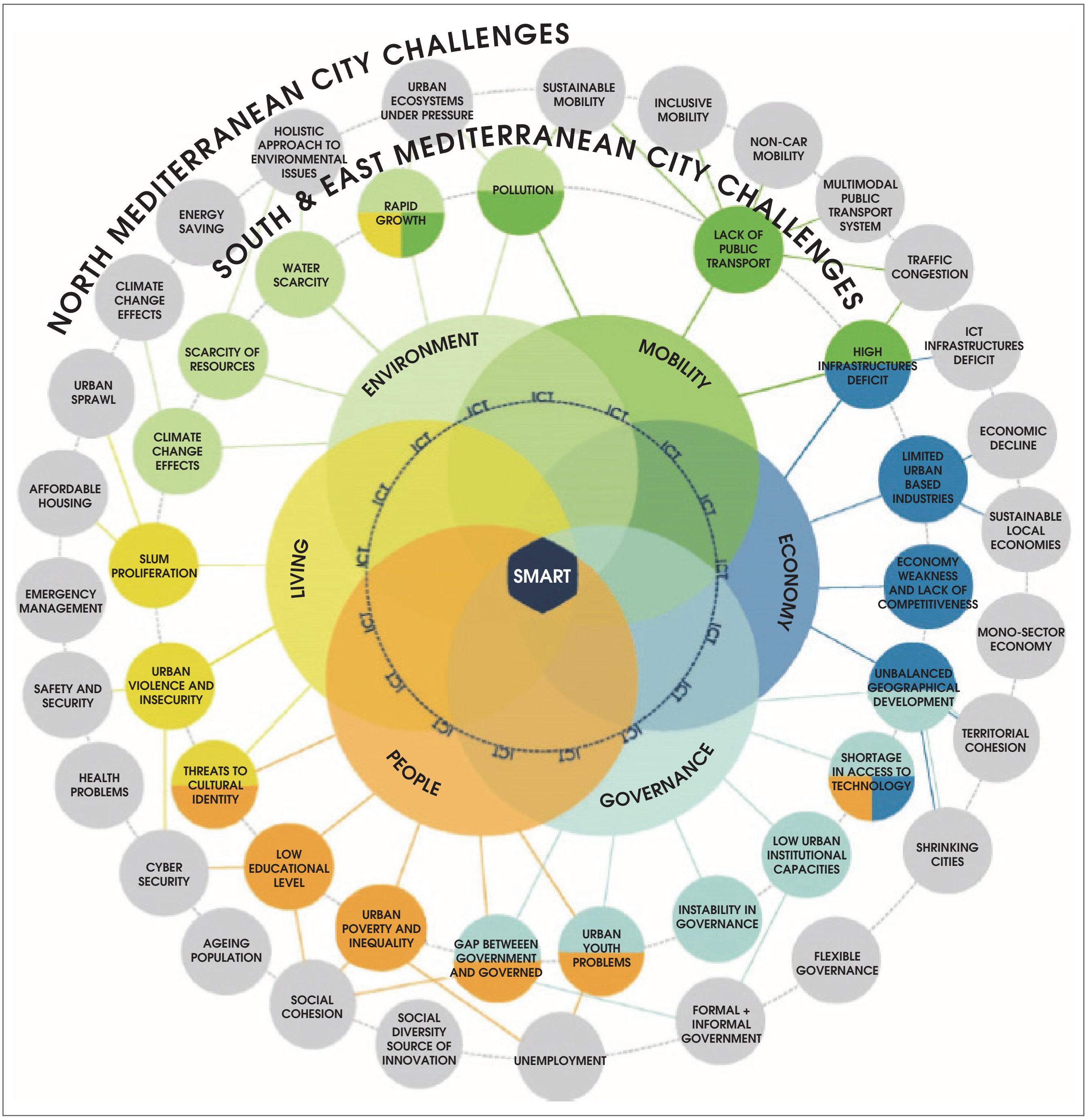

Figure 3: Relations between smart city dimensions, South & East Mediterranean challenges and general city challenges. Source: A. Monzon (2015)

US$6,991 respectively). Yet, in terms of passenger cars per 1,000 persons, the difference is very small (217 cars and 208 cars). Another comparison is the public transport seat km of service per capita (5,535 and 1,331 respectively); the Klang Valley provides much less. Notice the average network speed for both HIA and Klang Valley (31.3 km per hour and 28.1 km per hour respectively); the difference is slight which indicates that Klang Valley traffic has not come to a standstill yet. So, though the Klang Valley is car-dependent, it has not reached traffic saturation yet.

Benefits of transit-based system. The opposite of traffic congestion is seamless flow of traffic through adopting an urban transit system. By eliminating traffic congestion, the benefits are numerous, according to the American Public Transportation Association (2018). There is no wasting of time, no delay for appointment, no wasting of fuel and less air pollution/carbon dioxide emission, less car maintenance costs, less incidents of road rage, less spillover to other roads and less chance of collision on the roads [11].

Diaz and Mclean (1999) conducted a survey of 12 transit agencies which studied how transit developments affected property value [12]. Two major benefits were noted: Transit investment allowed better accessibility to other parts of a region from stations and more land spaces were opened up though these were previously not accessible and deemed unattractive. The quantum of increased property value in each case can be attributed to function of accessibility to employment, pedestrian accessibility, market penetration and development impacts. As argued by *Mohammad et al.,* (2013), implementing transit agencies should be careful to plan the alignment of their routes, and locations of the station in order to attract more commuters [13]. Another rail transit study undertaken for Shanghai, Pan and Zhang (2008) provided empirical evidence that supported classical land economic theories that with better accessibility, "higher development intensity and more capital–intensive land use occurs near the transit stations" [14].

In the next section we learnt from Ir. Dr Ooi's lecture that consultants/contractors met various geological challenges in the course of building an urban transit system in Kuala Lumpur.

GEOLOGICAL CHALLENGES OF UNDERGROUND KL

What are the unique challenges of Kuala Lumpur's geology, in particular the infamous KL Limestone Formation? "The construction of each underground structure/tunnel is a remarkable adventure, as it must be driven in a particular site featuring a rock mass in no way similar to any another," said Ir. Dr Ooi.

"The features encountered in KL Limestone Formation included but were not limited to the highly erratic rock head, highly developed fissures and intricate three dimensional network of solution channels littered with ubiquitous cavities, vertical cliffs, overhangs, and were consistent with Extreme Karst classification" according to *Waltham & Fookes* [15]. This karstic feature posed many problems to tunnelling as well as the design and construction of deep underground retention structures and therefore was rightly classified as potentially high risk.

Ooi and Ha [16, 17] summarised the challenges of tunnelling and deep excavation works in KL karsts. Key challenges included the difficulties in accurately defining the bedrock profile as well as the sizes, trends and depth of cavities and solution channels. The consequential impact of any groundwater flow and potential loss of material (sinkhole) through solution channels in karst could have far-reaching consequences, even up to great distances when the delicate balance of the in-situ groundwater condition was compromised [17].

Klados et al., [18] shared experiences in managing tunnelling challenges through the KL Karst Formation using the Variable Density Tunnel Boring Machine (VD TBM), a first-of-its-kind in the tunnelling industry. The VD TBM was conceptualised by Malaysian MMC-Gamuda JV through exhaustive research and collaboration with TBM supplier Herrenknecht AG and Ruhr-University.

The completion of the MRT1 line not only transformed KL's underground but also the heart of Malaysia. It would be remiss to not highlight the importance of the role of MRT in Kuala Lumpur's continuing evolution into a liveable, world-class city in the future. It has changed the landscape of underground transportation significantly with the least social and environmental impacts while maintaining the current "cityscape".

CONCLUSION

In trying to understand the motivations behind constructing the MRT1 and MRT2 lines, this article answered the three questions. First, an established liveable city is one that meets the mobility needs of its residents. Second, the urban transit system is the only means to overcome traffic congestion as we have learnt from the experiences of Singapore and Hong Kong. Third, by going underground to build the transit stations and the requisite tunnelling, consultants/contractors faced unique challenges in the KL Limestone Formation, which were eventually resolved using VD TBM. ■