Road logistics connectivity and container drayage model in enhancing urban logistics of new development area in Hong Kong

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Abstract

Suffering from land scarcity, a government urban logistics initiative on Hung Shui Kiu New Development Area (HSKNDA) is planned in Hong Kong, suggesting the reconsolidation of the container depots and introducing multi-storey cargo centre as a new model. The centre serves as similar role of urban consolidation center (UCC) in city logistics but located within the city of Hong Kong. This can increase land use and, at the same time, maintain logistics connectivity and competitiveness of Hong Kong with neighbouring cities. Most importantly, the consolidated cargo centre in Hung Shui Kiu can reduce the number of freight vehicles affecting the residential areas. Hung Shui Kiu, an area located in the northwest of Hong Kong, is proposed to be one of the potential areas to provide logistics back-up yard services. In assessing the potential of HSKNDA for logistics use and its impact towards the environment of congested urban area, the road logistics connectivity is evaluated with graph theory-based network metrics. A novel container drayage optimization model with consideration of the

Road Network Data	Measurements before HSKNDA	Measurements after HSKNDA	Connectivity Indexes	Macro-analysis			Micro-analysis		
				Values before HSKNDA	Values after HSKNDA	Impact on HSKNA Change	Values before HSKNDA	Values after HSKNDA	Impact on HSKNA change
Real Nodes (*R*)	5,240	5,219	Intersection Density	8.6450	8.6104	-0.40%	9.6639	6.7227	-30.4%
Dangle Nodes (*D*)	741	754	Street Density	1.7378	1.7502	-0.71%	1.8763	2.9294	+56.1%
Total Nodes (*N*)	5,981	5,973	Connected Node Ratio	0.8761	0.8738	-0.26%	0.7041	0.5333	-24.2%
Link Number (*L*)	7,888	7,845	Beta (Link-Node) Ratio	1.3188	1.3134	-0.41%	1.4082	1.0556	-25.0%
Link Length (*l*) (km)	1,053	1,061	Gamma Index	0.4398	0.4380	-0.41%	0.4946	0.3598	-27.3%
			Alpha Index	0.1596	0.1569	-1.69%	0.2147	0.0343	-84.0%

Table 1. Road network data and the connectivity analysis results on Hung Shiu Kiu Development Area

network metrics is developed in this paper to enhance the drayage operations efficiency and reduce the impact to the nearby residents. Road network files from 2009-2015 are analysed using ArcMap and the road connectivity are evaluated on its completeness, circuitry and complexity using alpha index (α), beta index (β or link-node ratio), connected node ratio (*CNR*), intersection density (*ID*), street density (*SD*) and gamma index (γ). The results generated in Table 1 will be discussed in the presentation, e.g. shorter road length and higher road turns of a road limits the movement of 40ft container truck, extension of road link and increase of street block after HSKDA, etc.

Road connectivity metrics, as key factors for the container drayage effectiveness, is developed in the model. The multi-objective optimisation model is built with twenty constraints aims to minimise the total traveling distance, truck fuel cost, container rental cost and inventory of container movement with time window within the study area while satisfying the customer supply-and-demand requirements, and time-cost variable factors are involved in the equation (Equation 1) (Notations, decision variables, and constraints will be shown in paper or presentation). The model is applied and covered on the Hung Shui Kiu and two major container terminals in Hong Kong.

$$\begin{aligned} Z(F^{l,t}, C^{f,r,I}) = & \sum_{i \in Imp} \sum_{j \in Exp} \left[\sum_{x=0}^{n} \sum_{k=0}^{n} (x_{id}^{s,k} + x_{ij}^{s,k}) * L \right] F^{l} \\ & + \sum_{i \in Imp} \sum_{j \in Exp} \left[\sum_{x=0}^{n} \sum_{k=0}^{n} (x_{dj}^{s,k} + x_{ij}^{s,k}) * T \right] F^{t} \\ & + \sum_{i \in Imp} \sum_{j \in Exp} \left[\sum_{x=0}^{n} \sum_{k=0}^{n} (x_{id}^{s,k} * l_{id}^{s,k}) + (x_{dj}^{s,k} * l_{dj}^{s,k}) + (x_{ij}^{s,k} * l_{ij}^{s,k}) \right] C^{f} \\ & + \left[\sum_{i \in Imp} \sum_{j \in Exp} \sum_{x=0}^{n} \sum_{k=0}^{n} \left(x_{id}^{s,k} + x_{de}^{s,k} + x_{r}^{s} \right) \right] C^{r} + C_{d}^{I}(V_{d}^{s}) \end{aligned} \quad (1)$$

Comparing the road connectivity of the circumstances before and after HSKNDA, the results showed that the alpha, beta and gamma indexes changed slightly but the node number, link number and link length are decreased, benefiting container truck movements. The container drayage model aims to minimise the total travelling distance and time, truck fuel costs, container rental costs and inventory costs, covering the inbound laden pickup, inbound empty return, outbound empty pickup, outbound laden return container movements, and emission impact to nearby residents. A novel shippers pool model is proposed for the drayage problem to minimize travelling opportunity costs and system operating costs. The proposed approach has been applied to four scenarios and compared with the traditional drayage approach. The results showed that both opportunity cost and operating cost obtained by shippers' pool approach have been reduced significantly for the four simulated scenarios compared to the results obtained by the traditional approach. The model also reduced the road congestion and vehicle emission in residential areas. The research work contributes in evaluating the road connectivity in the new HSKNDA and develop a novel container drayage model to enhance the future urban freight transport logistics operations efficiency and sustainable environmental condition of city logistics in the new development area.