TRAFFIC IMPACT ASSESSMENT OF LARGE-SCALE WATER IRRIGATION PROJECT

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Abstract

Considering Thailand as one of the largest agricultural countries, the requirement of transportation infrastructure should not only be limited to accommodate general traffic but also the transportation of crops and agriculture products during the harvest seasons. Recently, the Thai Government initiated a plan to construct a network of reservoirs within the northeastern region, aiming at improving existing water irrigation system particularly in the areas where the effective irrigation system is needed. It is expected to bring in the opportunities to expand the cultivation areas, increase the economy of scale and enlarge the extent market of area. As the consequences, traffic impact assessment needed to be studied to assure the service quality of the related transportation facilities. This paper proposes the traffic impact assessment approach of a large-scale water irrigation project that affects the regional road infrastructure network. The study takes production capacity, size of cultivation area, and harvest seasons of each crop or agricultural product into account. The expansion of the water irrigation system for the northeastern of Thailand has been used as a case study.

Keywords: Large-scale, Traffic Impact, Water Irrigation, Logistics, Thailand

1. INTRODUCTION

The initiation of a new infrastructure and the need of transportation have been known as the common concomitance. Transportation requirement generally derives from the demand generated or attracted by the initiated infrastructure. The basis of demand forecasting usually applies the characteristics of the infrastructure such as the number of households, the average number of persons per household, area floor spaces, number of parking spaces, types of

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activities, etc. as influencing factors. In order to assess the service quality of the related transportation facilities within the influence areas, the level of infrastructure utilization which is represented by a ratio between transport demand and network capacity must be determined. Given that the level of service (LOS) of transportation facilities is to be maintained at its standard, the prioritization of transport network improvement should be in line with the assessed LOS. This process is defined as traffic impact assessment.

Considering Thailand as one of the largest agricultural countries, the requirement of transportation infrastructure should not only be limited to accommodate general traffic but also the transportation of crops and agriculture products during the harvest seasons. Recently, the Thai Government initiated a plan to construct a network of reservoirs within the northeastern region, aiming at improving existing water irrigation system particularly in the areas where the effective irrigation system is needed. It is expected to bring in the opportunities to expand the cultivation areas, increase the economy of scale and enlarge the extent market of area. As the consequences, traffic impact assessment needed to be studied to assure the service quality of the related transportation facilities. This paper proposes the traffic impact assessment approach of a large-scale water irrigation project that affects the regional road infrastructure network. The study takes production capacity, size of cultivation area, and harvest seasons of each crop or agricultural product into account. The expansion of the water irrigation system for the northeastern of Thailand has been used as a case study.

The concept, supporting backgrounds, and objectives of region-wide water irrigation project are described in the next section. The approach to estimation of the change in transport supply and demand corresponding to the initiation of region-wide water irrigation project is described in section 3. Change in cultivation areas between pre- and post- project implementation, harvest seasons, productivity, distribution channels and transportation network for each crop, are also incorporated into the investigation. Finally, the assessment of traffic impact of the corresponding change in transport demands on the regional road network is described in section 4.

2. THAILAND NORTHEASTERN WATER IRRIGATION PROJECT

Although, Thailand is one of the largest agriculture countries, however the cultivation relies mostly on rainwater. The service area of the existing irrigation system is only within the boundary of dam catchment areas, whereas for the others, the demand for water is still immense. The northeastern region, where most farmland is contained, is facing a problem of inaccessible irrigation and insufficient water in some parts of the region. Such problem leads to unproductive cultivation areas during the harvest seasons, and finally ends up with drought areas. The problem of unproductive lands reduces the income and quality of life of the local people and is realized as a major cause of poverty in the region. In order to relieve the problem, the Thai Government proposes a grant for the provision of region-wide water

irrigation.

The objective of region-wide water irrigation planning is to expand the existing irrigation network so that the agriculture land can be cultivated productively throughout the year. According to the study done by the Department of Water Resources, the Ministry of Natural Resources and Environment, the project could expand the water irrigation area coverage from the current 71.40 Million Rais to 104.60 Million Rais[1]. As a result, the productive farmland will be increased significantly with a high productivity of the harvest crops. The consequence is the need of transportation of crops to local distribution centers or elsewhere, domestically and internationally.

The proposed water irrigation network will cover 19 critical drought areas of the northeastern region and would result in sufficient water resource for cultivation all year round. The planned irrigation network for the northeastern region is presented in **Figure 1**.

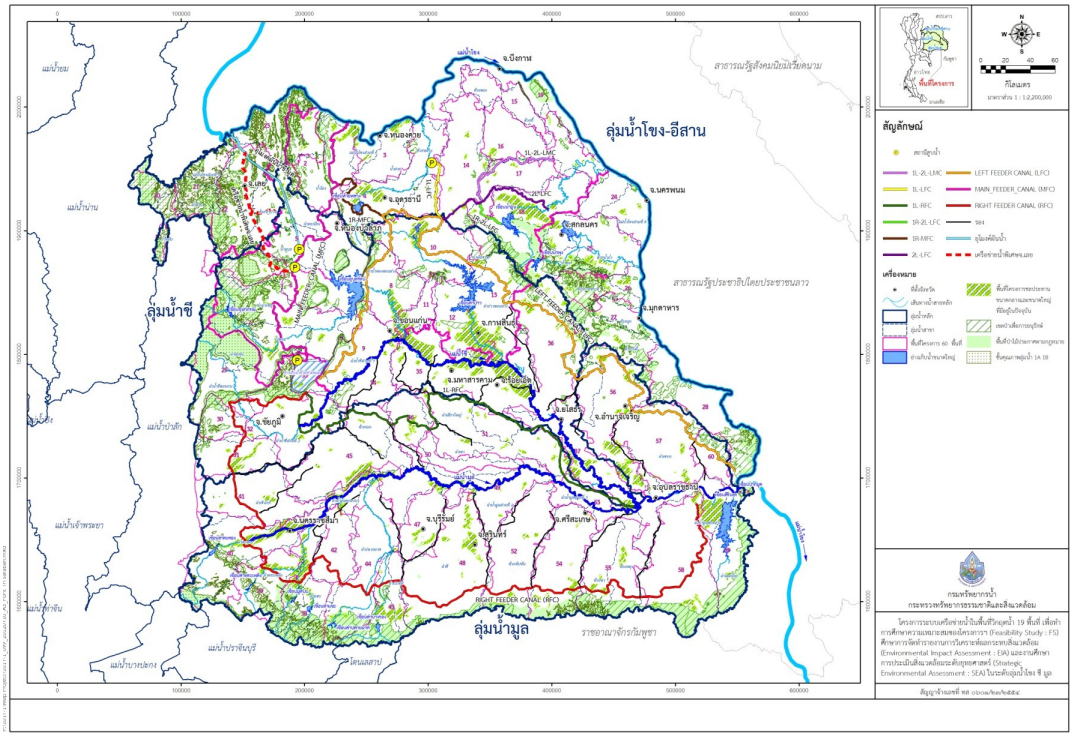

Figure 1: Region-wide irrigation network project in the northeastern
(Source: Department of Water Resources, Ministry of Natural Resources and Environment)

3. LITERATURE REVIEWS OF PREVIOUS STUDIES

Rural roads are important to the country economics as they serve the functions of access

[1] 1 hectare = 6.25 Rais

to raw material sources, industrial zones, intermodal facilities, markets, and gateways. Planning and assessment of level of service of rural roads are unique and different from the practice adopted in urban highway according to the following reasons:

- Traffic impacts on rural roads are seasonal. Peak periods occur during crop production and harvesting and holiday seasons different from urban traffic which is congested all year round due to commuting trips.
- Rural households have more vehicles and are more likely to have older vehicles, especially pick-up trucks.
- Rural households account for more vehicle miles of travel with faster travel speed;
- The typical vehicle types using rural roads include automobiles, motorcycles, pickup trucks, farmer-owned tandem axle and semi-trucks, farm combines, and farm tractors pulling various types of farm equipment. Other vehicle types include commercial trucks, garbage trucks, and school buses while most vehicles using urban roads include sedans, motorcycles, van and buses.

The evidences supporting the above arguments appear in Sebaaly et al. (2003), USDOT (2005); while some studies focus on rural road management including Anderson and Sessions (1991), Tolliver et al. (2011), Babcock and Alakshendra (2012); only a few focus on how seasonal effects impact traffic loading onto rural road network such as Kansas DOT (2009). The study on how to conduct traffic impact assessment of large-scale water irrigation project is very rare and remains as a gap in knowledge.

4. RESEARCH METHODOLOGY

From the Thai Government region-wide water irrigation project as described above, it can be seen that there is a need in demand analysis of the forecasting traffic due to the transportation of the harvested crops. Research methodology as shown **in Figure 2** begins with product classification and clustering. For each crop, annual crop harvested can be estimated by multiplying harvest area with productivity. Adjusted by seasonal factors, peak-season crop harvested can be determined. Generally, each crop cannot be consumed without processing. Therefore, the process of each crop and conversion factor must be identified to convert the quantity of crop harvested into process goods which is delivered to various market segments including domestic consumption and exports via borders and gateways. Investigation of modal share and load factors of each processed goods allows planners to identify truck movement and the assigned transport routes. The assigned truck movement combined with background traffic are converted into Passenger Car equivalent Unit and compared with the road link capacity to conclude how much road space is occupied which reflect the level of service of that each particular link.

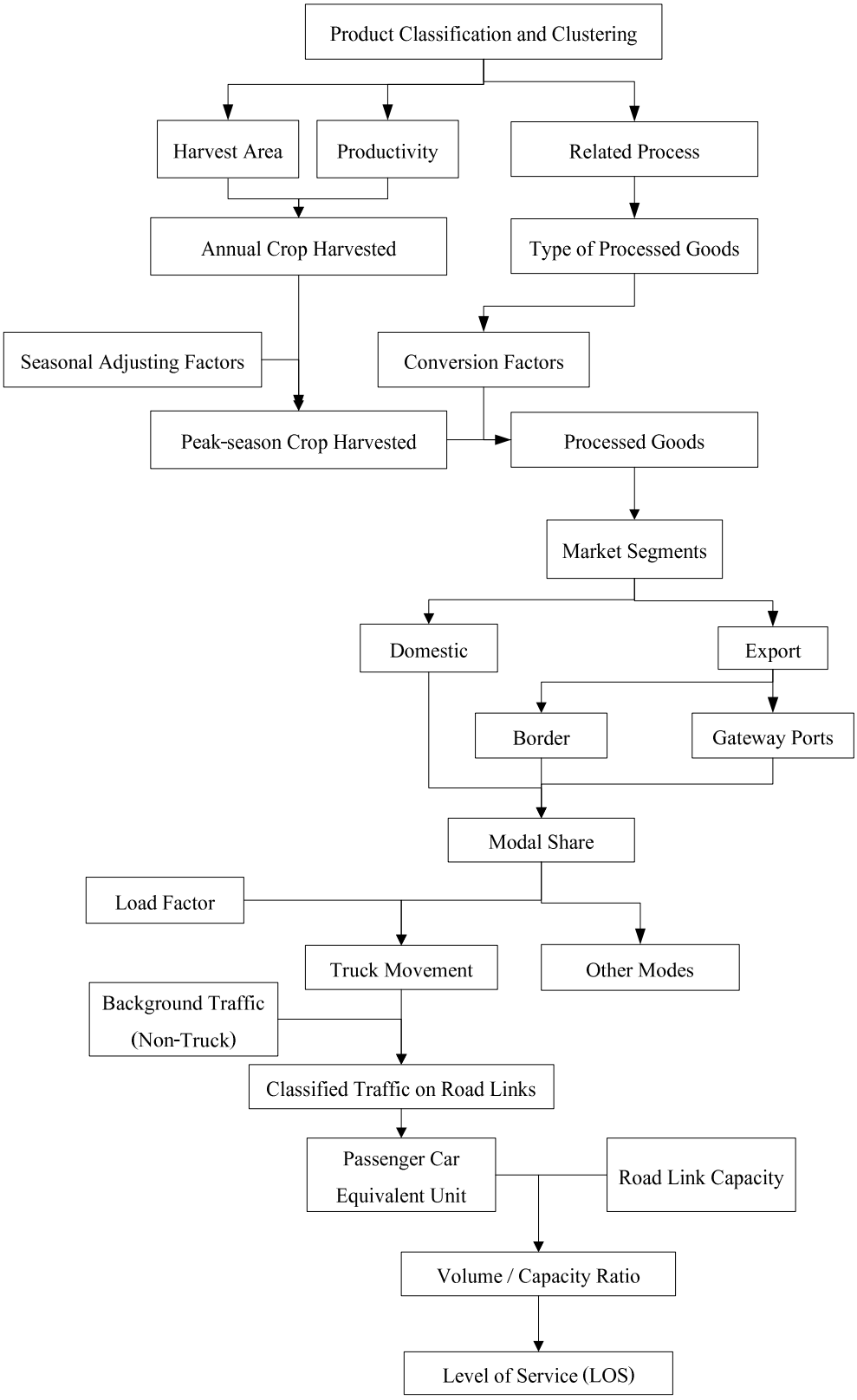

Figure 2: Research Methodology

4.1 Harvesting Forecast

Since the expansion of the irrigation system in the area leads to an increasing of the overall harvesting, the analysis of crops zoning, production and harvesting seasons is required for further traffic demand forecasting. In this study, those issues have been analyzed by the Department of Water Resources. The crops which are selected for this study are based on the top produced crops of the region which are rice, rubber, sugar cane, palm and corn. The summary of the crops zoning are presented in **Figures 3 to 7**.

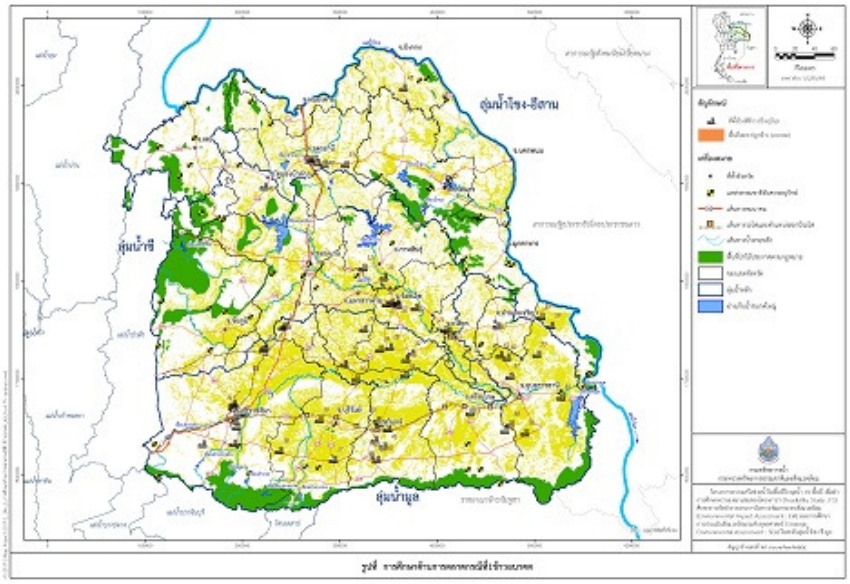

Figure 3: Agriculture zones for rice in the northeastern
(Source: Department of Water Resources, Ministry of Natural Resources and Environment)

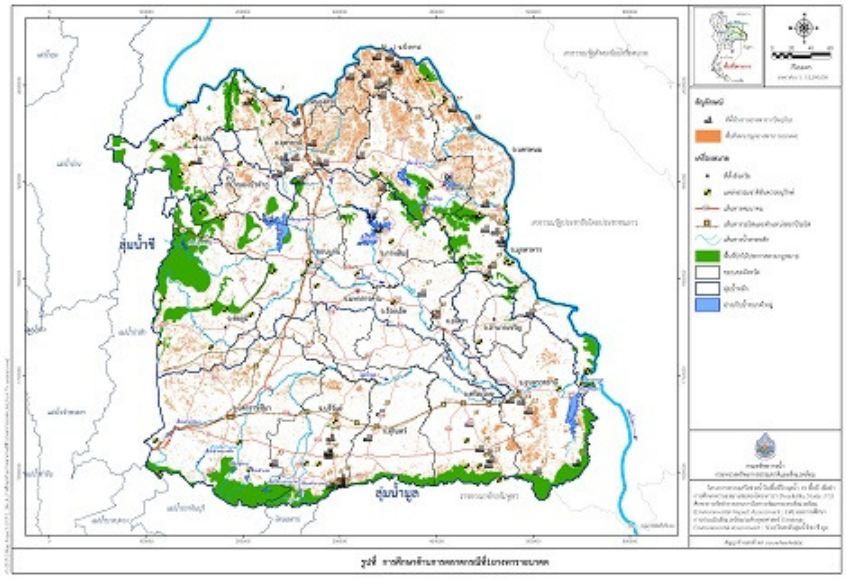

Figure 4: Agriculture zones for rubber in the northeastern
(Source: Department of Water Resources, Ministry of Natural Resources and Environment)

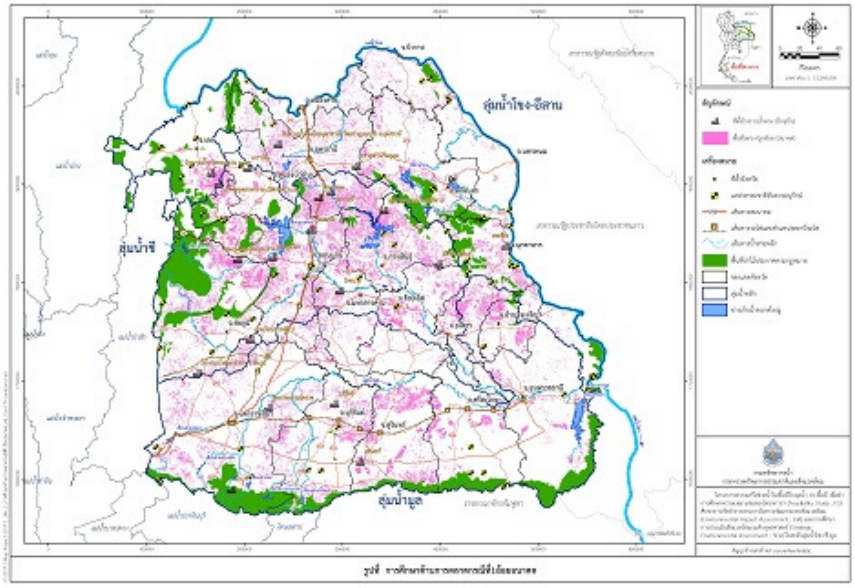

Figure 5: Agriculture zones for sugar cane in the northeastern
(Source: Department of Water Resources, Ministry of Natural Resources and Environment)

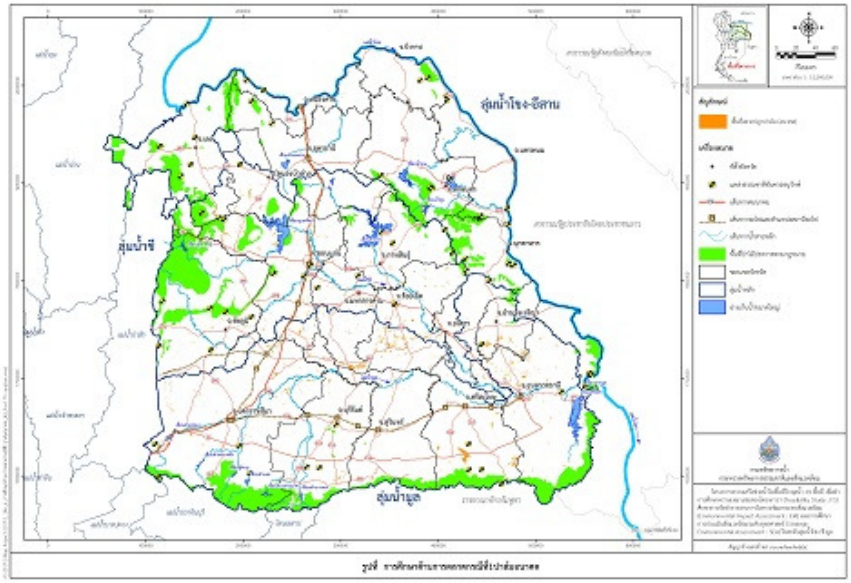

Figure 6: Agriculture zones for palm in the northeastern
(Source: Department of Water Resources, Ministry of Natural Resources and Environment)

In addition, the forecasted cultivation land for each type of crops by provinces is summarized in **Table 1**. The forecast of crop production as presented in **Table 1** is used in estimating the number of additional truck traffic to the road network. In the next section, the method used in the estimation will be described along with the results of traffic demand, distributed to the road network.

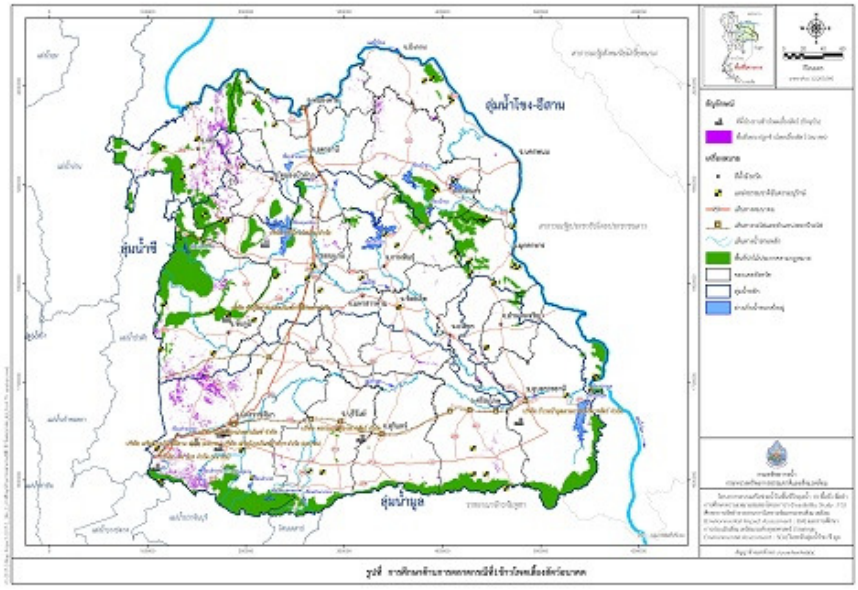

Figure 7: Agriculture zones for corn in the northeastern
(Source: Department of Water Resources, Ministry of Natural Resources and Environment)

The expansion of the agriculture land after the new water irrigation network is in effective presented in the previous section, however, each crop has different cultivation and harvesting seasons. Therefore, to reflect the real crop transport demand, the analysis of the traffic demand is needed to be considered on the monthly basis as shown in **Equation 1.**

$$\Sigma_i \, VM_i = \Sigma_i \, (P_i \times A_i / M_i) \qquad (1)$$

where VM_i is the total production of crop type i in month M (tons)

P_i is the production rate of crop type i per rai in that month (tons)

A_i is the agriculture land/area of crop type i

M_i is the number of months its harvesting period of crop i

4.2 Transport Demand Forecast

The forecasted crop production, the harvest seasons and its area of cultivation has been analyzed provincially to determine the monthly agricultural output. This output is then distributed to the potential destinations including, domestic and international gateways. This study assumes 15 tons truck load in calculating total number of truck traffic. Therefore, for each type of crop i, the forecasted truck demand can be determine by **Equation 2.**

$$T_i = \Sigma_i \, (VM_i) / 15 \qquad \mathbf{(2)}$$

where T_i is the total truck traffic for transporting crop i in month M (trips/month)

VM_i is the total production of crop type in month M (tons)

Table 1: Forecast of the cultivation land by provinces in the northeastern

Province	Rice		Corn		Palm		Sugar Cane		Rubber	
	pre-	post-	pre-	post-	pre-	post-	pre-	post-	pre-	post-
Karnlasin	607,426	936,163	4,147	7,830	6,317	11,672	823,223	958,826	146,107	150,082
Konkhen	1,839,130	1,987,482	50,707	51,322	65,673	68,917	1,247,126	1,289,136	267,225	273,004
Chaiyaphum	1,319,195	1,453,964	136,392	144,387	19,814	20,590	1,138,944	1,154,894	406,755	410,855
Nakornnayok	-	-	-	-	-	-	-	-	-	-
Nakornpanom	989,595	1,026,541	7,392	7,446	3,031	3,938	96,483	109,191	731,387	741,539
Nakornrajsima	2,948,537	3,416,271	443,843	444,771	69,755	74,578	1,718,897	1,776,224	688,740	692,059
Bungkarn	706,234	706,999	10,143	10,143	1,799	1,799	194,782	194,974	839,014	839,103
Burirum	2,834,046	2,962,252	25,592	26,849	21,422	28,345	551,180	604,426	334,521	342,282
Prajeenburi	-	-	-	-	-	-	-	-	-	-
Phitsanulok	-	-	-	-	-	-	-	-	-	-
Petchchaboon	46	46	92	92	-	-	0	0	-	-
Mahasarakam	1,502,549	1,642,454	2,957	3,115	57,495	60,559	365,951	390,268	83,592	83,684
Mukdaharn	221,257	228,070	2,566	2,725	688	922	281,372	303,044	82,941	84,563
Yasothorn	899,602	981,190	659	659	15,035	15,670	316,809	331,791	60,460	60,667
Roied	2,214,027	2,422,561	35,025	36,925	85,890	87,149	359,022	426,545	103,818	103,943
Loei	344,757	351,412	340,274	342,771	2,164	2,538	592,935	595,426	316,686	319,335
Srisaket	1,749,713	1,818,958	29,783	30,289	72,102	73,186	503,856	557,854	312,769	319,761
Sakonnakorn	1,137,503	1,319,555	41,699	42,086	1,469	3,138	418,276	491,690	944,513	960,248
Surin	2,400,546	2,474,986	8,688	9,435	11,565	14,004	442,102	503,081	154,654	156,280
Nongkai	350,450	417,356	27,055	27,547	1,611	7,063	140,884	147,990	526,644	546,840
Nongbualumpoo	496,406	498,958	59,699	60,377	15,853	15,853	204,239	204,246	180,924	184,810
Amnartjaroen	403,848	444,185	5,008	5,275	37,654	40,427	135,465	149,996	56,830	56,841
Udonthani	1,515,401	1,647,057	8,376	9,574	2,701	4,221	1,399,866	1,417,844	1,415,613	1,432,198
Ubonratchathani	3,483,785	3,715,447	22,811	23,029	74,015	80,981	420,545	503,170	674,520	703,780

(Source: Department of Water Resources, Ministry of Natural Resources and Environment)

Unit: Rai

According to Thailand's exporting statistics for agriculture products, crop product is consumed domestically at the average of 30 percent, except the rubber which is 100 percent export. For the domestic demand, the traffic is being distributed to the target distribution centers or local industrial zones related to the processing of particular products. The rest is being transported to the international gateway such as deep sea ports or international borders for exporting.

4.2.1 Domestic Demand

As described, the domestic demand of 30 percent except rubber is to be distributed locally. Therefore the target destinations for domestic use of the product are determined based on national consumption. The distribution of the raw agriculture product firstly designated to the local factories for processing. For example, the raw product of rice is firstly distributed to the local rice mills and packing stations. The average weight proportion of milled and un-milled rice is used to calculate the net weight of the rice output. Since the major distribution centers for national consumption are located in the central region approximately in the vicinity provinces around Bangkok, the transport route used in determining the distribution of traffic are the major highways to the region described. The products analyzed in this study including rice, corn, palm, sugar cane and rubber. **Table 2** presents the example

of the distribution of additional traffic demand for domestic consumption.

Table 2: Examples of the distribution of additional traffic demand for domestic consumption

	Additional Area and Traffic per Crop Types									
	Rice		Corn		Palm		Sugar Cane		Rubber	
Province	Rai	vehicle/ day	Rai	vehicle/ day	Rai	vehicle/ day	Rai	vehicle/ day	Rai	vehicle/ day
Karnlasin	328,737	25	3,683	1	5,356	1	135,603	165	3,975	1
Konkhen	148,351	11	615	1	3,244	0	42,010	51	5,779	1
Chaiyaphum	134,768	10	7,995	1	776	0	15,950	19	4,101	1
Nakornnayok	-	-	-	-	-	-	-	-	-	-
Nakornpanom	36,946	3	54	1	906	0	12,708	15	10,152	1
Nakornrajsima	467,734	36	928	1	4,823	1	57,327	70	3,319	1
Bungkarn	765	0	-	-	-	-	193	0	89	1
Burirum	128,206	10	1,257	1	6,923	1	53,246	65	7,761	1
Prajeenburi	-	-	-	-	-	-	-	-	-	-
Phitsanulok	-	-	-	-	-	-	-	-	-	-
Petchchaboon	-	-	-	-	-	-	-	-	-	-
Mahasarakam	139,905	11	158	1	3,064	0	24,317	30	92	1
Mukdaharn	6,813	1	159	1	233	0	21,672	26	1,621	1
Yasothorn	81,588	6	-	-	635	0	14,982	18	207	1
Roied	208,534	16	1,901	1	1,258	0	67,523	82	124	1
Loei	6,655	1	2,498	1	374	0	2,491	3	2,649	1
Srisaket	69,245	5	507	1	1,084	0	53,999	66	6,992	1
Sakonnakorn	182,052	14	387	1	1,669	0	73,414	90	15,735	1
Surin	74,440	6	747	1	2,439	0	60,979	74	1,626	1
Nongkai	66,906	5	492	1	5,452	1	7,106	9	20,195	1
Nongbualumpoo	2,552	1	679	1	-	-	6	0	3,886	1
Amnartjaroen	40,337	3	267	1	2,773	0	14,531	18	11	1
Udonthani	131,656	10	1,198	1	1,519	0	17,979	22	16,585	1
Ubonratchathani	231,661	18	218	1	6,966	1	82,625	101	29,261	1

4.2.2 External Demand

The concept of the external demand is based on the assumption that there is an international demand of goods for exporting. The external demand is assumed to be 70 percents of the total production and is distributed to the highway network and intermodal facilities within the region. Because, most of the export is designated to the Europe, USA, East Asia and Japan, the final destination of the external demand is mainly the deep sea ports in the eastern region. The proportion of 70:30 as the estimation of the modal spit between road/rail transport studied by the Office of Transport and Traffic Policy and Planning is used to split the demand by mode for each destination. The distribution of additional traffic demand to the major road network designated to Thailand's international gateways can be summarized in **Table 3**.

Table 3: Examples of additional traffic, designated to the international gateways

Province	Additional Area and Traffic per Crop Types									
	Rice		Corn		Palm		Sugar Cane		Rubber	
	Rai	vehicle/ day	Rai	vehicle/ day	Rai	vehicle/ day	Rai	vehicle/ day	Rai	vehicle/ day
Karnlasin	328,737	59	3,683	1	5,356	2	135,603	386	3,975	1
Konkhen	148,351	27	615	1	3,244	1	42,010	120	5,779	1
Chaiyaphum	134,768	24	7,995	3	776	1	15,950	45	4,101	1
Nakornnayok	-	-	-	-	-	-	-	-	-	-
Nakornpanom	36,946	7	54	1	906	1	12,708	36	10,152	1
Nakornrajsima	467,734	84	928	1	4,823	2	57,327	163	3,319	1
Bungkarn	765	1	-	-	-	-	193	1	89	1
Burirum	128,206	23	1,257	1	6,923	2	53,246	151	7,761	1
Prajeenburi	-	-	-	-	-	-	-	-	-	-
Phitsanulok	-	-	-	-	-	-	-	-	-	-
Petchchaboon	-	-	-	-	-	-	-	-	-	-
Mahasarakam	139,905	25	158	1	3,064	1	24,317	69	92	1
Mukdaharn	6,813	1	159	1	233	1	21,672	62	1,621	1
Yasothorn	81,588	15	-	-	635	1	14,982	43	207	1
Roied	208,534	37	1,901	1	1,258	1	67,523	192	124	1
Loei	6,655	1	2,498	1	374	1	2,491	7	2,649	1
Srisaket	69,245	12	507	1	1,084	1	53,999	154	6,992	1
Sakonnakorn	182,052	33	387	1	1,669	1	73,414	209	15,735	1
Surin	74,440	13	747	1	2,439	1	60,979	173	1,626	1
Nongkai	66,906	12	492	1	5,452	2	7,106	20	20,195	1
Nongbualumpoo	2,552	1	679	1	-	-	6	1	3,886	1
Amnartjaroen	40,337	7	267	1	2,773	1	14,531	41	11	1
Udonthani	131,656	24	1,198	1	1,519	1	17,979	51	16,585	1
Ubonratchathani	231,661	42	218	1	6,966	2	82,625	235	29,261	1

4.3 Traffic Impact Assessment

From the forecasting of domestic and external demand, the additional truck traffic is combined with other background traffic that is not related to additional crop harvest from the project. The background traffic needed to be averaged daily from the traffic collected throughout the year technically called Annual Average Daily Traffic (AADT). The combined traffic demand to be distributed into the road network somehow needed to be converted into a unified passenger car equivalent unit (PCU) using a so called PCU factors as each type of vehicles occupies different amount of space on the road. Typically a car, a truck or a bus, and a motorcycle have 1, 2.5, and 0.33 PCUs, respectively. The distributed traffic into the highway network is used in analyzing the traffic impact of the project. The average growth rate of the region is used to determine the 10-year future demand as the pre-implementation traffic demand. By comparing pre- implementation and post- implementation traffic, the traffic impact of the project could be assessed.

According to the highway capacity manual (2000), the 'capacity' of the facility is defined as the maximum amount of traffic that the facility can carry under prevailing conditions of geometry, traffic mix and location and the Level of Service (LOS) is defined as a qualitative measure that describes traffic conditions in term of speed, travel time, freedom to

maneuver, comfort, convenience, traffic interruptions, and safety. For a highway section, the LOS can be explained by the volume per capacity ratio (V/C) which varies from a low of 0 (free flow) to values sometimes greater than 1.0 (severely/heavily congested). The suggested levels of service (LOS) and related V/C by HCM (2000) is as shown in **Table 4**

Table 4: Level of service (LOS) and vehicle per capacity (V/C) ratio

LOS	V/C Ratio	Description
A	0.00 – 0.35	Free flow. No traffic interruption. Best operating conditions.
B	0.35 – 0.58	Reasonably free-flow with some interruption.
C	0.58 – 0.75	Constrained constant flow below speed limits, with additional attention for safe operations.
D	0.75 – 0.90	Approaching unstable flow. Severely restricted in maneuverability.
E	0.90 – 1.00	Unstable flow near capacity.
F	> 1.00	Heavily congested flow and traffic demand exceeding capacity. Worst operating conditions.

It is noted that since traffic demand relies on the type of crops cultivated in each sub-area and harvesting seasons, the impact is assessed on the monthly basis. For each highway section, the results during the critical month are used to determine the impact to the road network. The example of traffic impacts on road network during its critical month is presented in **Table 5**. From the results, it is seen that although the region-wide water irrigation project coverage area largely covers the agriculture land in the northeastern region. The impact of the increase in crop transport demand on road network is not significant. It is noted that the highway sections analyzed in this study are mostly the inter-city highway which function as a linkage between provinces or as a regional highway network. Therefore, the designed capacity of the highway network is quite high while the general traffic demand is relatively low.

However, **Table 5** shows that there are some of the highway sections which consist of the Highway No.2 section 1000 and Highway No.12 section 1602 that post-implementation LOS dropped from LOS A to D. This is because the former is the major linkage between Khonkaen City Center and Udornthani which generally accommodates already high traffic demand. The latter section, Highway No.12 section 1602, links between Khonkaen City and Chumpae District which is one of the most popular residential areas. It is noted that in term of location on the overall network, Khonkaen is one of the biggest cities located in the heart of the northeastern region. Avoiding this part of the road network when traveling from the north and the east of this region would be very difficult. Therefore the combination of high

background traffic demand and additional traffic from agriculture products highly affects highway sections' V/C.

Table 5: Examples of traffic impacts on road network during the critical month

Highway No.	Section	Capacity	Without Project		With Project	
			V/C	LOS	V/C	LOS
12	1801	7,200	0.15	A	0.20	A
12	1802	7,200	0.09	A	0.12	A
214	100	2,400	0.28	A	0.38	A
2	1000	7,200	0.65	B	0.87	D
2	1101	7,200	0.12	A	0.17	A
12	1602	7,200	0.65	B	0.88	D
208	101	2,400	0.36	A	0.48	A
201	600	7,200	0.08	A	0.10	A
225	800	7,200	0.04	A	0.06	A
201	300	7,200	0.09	A	0.12	A
202	202	2,400	0.08	A	0.11	A
22	700	7,200	0.11	A	0.15	A
212	1100	7,200	0.09	A	0.12	A
212	1001	7,200	0.11	A	0.15	A
2	300	14,400	0.14	A	0.19	A
2	500	14,400	0.25	A	0.34	A
2	600	7,200	0.18	A	0.24	A
226	101	7,200	0.12	A	0.16	A
24	201	7,200	0.16	A	0.21	A
304	904	7,200	0.16	A	0.22	A

5. CONCLUSIONS AND RECOMMENDATIONS

This paper demonstrates the method of traffic impact assessment for an area-wide water irrigation project that affects the regional traffic demand. The expansion of water irrigation system for the northeastern of Thailand has been used as a case study. Since the demand for transporting crops varies across the harvest seasons, the demand is needed to be estimated on month by month basis. The harvest season of each crop is considered for analyzing the transport demand, distributed to each road section on the network. The estimation of traffic demand related to the cultivation involves trips generated by the local processing of the agriculture products and distributed to the distribution centers. These trips are referred to as domestic traffic demand. The study also estimates trips related to the external demand or

exporting trips. For Thailand agriculture products, the exporting trips are assumed to be distributed to the deep sea port located in the eastern part of the country. The combination of both domestic and external demand is used to determine the V/C and LOS of each highway section. The critical highway section where the LOS reaches the unacceptable stage will require a plan or scheme of traffic management similar to typical traffic impact assessment practice.

ACKNOWLEDGEMENT

The authors would like to express their gratitude to the Department of Water Resources, Ministry of Natural Resources and Environment for their courtesy in valuable data and information used in this research.

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