Environmental and Economic Impacts of Transit-Oriented Corridors in Korea

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Abstract
This study measures and estimates the potential environmental and economic impacts of introducing transit-oriented corridors in Korea. By developing a TOC planning model concept through regression analysis, authors examine the relationship between TOC planning factors and transport modal share, and the impact of transit accessibility on transport modal choice. Several conclusions were drawn from the results; first, in order to promote mass transit, the area's residential and commercial features must be intensified through a combination of mixed-use and a low ratio of road. Second, the transit modal choice analysis revealed that accessibility to mass transit is an important variable in determining its usage, along with the number of blocks per unit area and the pedestrian environment of the vicinity. Third, the results suggest that strengthening city-wide reliance on mass transit is effective in reducing environmental hazards to a significant degree: with a ridership ratio increase expected in the range of 3.5 to 5.9%, the resulting decreased road traffic would reduce CO₂ emissions by 391 to 686 thousand tons. Finally, in terms of boosting the regional economy, higher pedestrian volumes of commuters would increase annual income for neighborhood retailers in the range of 7.4 to 13.6 million dollars.

Keywords: transit-oriented corridor; transit-oriented development; carbon reduction; modal choice model; regional revitalization

1. Introduction
The world is in the midst of a climate change crisis. Al Gore argues that global warming poses a severe risk to the survival of humanity and now is the time for the current generation to create a better future for our descendants by making short term sacrifices and changing our excessive way of life (Gore, 2006). Efforts to curb global warming and form more sustainable societies and spaces are underway. The green city concept could spearhead these efforts, as it is an intensive urban policy agenda that addresses the environment while strengthening regional economic strategic competitiveness. The Korean government recently announced a national strategy of 'low-carbon green growth,' which includes compact spatial structure, mixed land use, more construction of mass transit and other urban management devices aimed at creating a versatile and unified green development policy. In particular, transportation and land use have been given top priority through a focus on transit-oriented development (TOD) and transit malls.

However, application of these development models is difficult in contemporary Korean cities as TOD in its generic form will not succeed without customization to integrate with existing urban regeneration projects. Korea, as a signatory state to the Kyoto Protocol, is obligated to further reduce greenhouse gas emissions by 2013. This is further incentive to establish an effective green city development policy that shares similar principles, bolstering future alternative policy measures.

The focus of this study is to configure a complement to TOC, the Transit-Oriented Corridor in the form of a transit route, through a combination of upgrades to the existing urban spatial structure and mass transit system along with district planning and development techniques to form a comprehensive development package. This study aims to verify whether or not TOC can contribute to the development of green cities, as at least twenty small to mid-sized cities are considering tramway plans in Korea. However, it is insufficient to assume that building a tram system will automatically transform the vicinity into a vibrant commercial and cultural cluster. Success is dependent on planning to encourage congruent development and regeneration of surrounding areas and will require new concepts, principles, and techniques.
This study's organization is as follows: first authors analyze established TOD and TOC concepts and planning principles, accounting for existing urban form and travel behavior. Next, a TOC planning model is developed and applied to Anyang City in order to examine its potential impact on access to mass transit, walking distances in the corridor, land use planning elements, and ridership modal selection. And this paper concludes with results and analysis focusing on the hypothetical impact of the TOC model on the local environment and economy. Spatial and statistical analysis was conducted using SPSS 12.0K, the TOC planning model was created with ArcGIS 9.2, and schematics were drafted in AutoCAD 2009.

The analysis site chosen for this study, Anyang, is one of the many satellite cities located in the Seoul Metropolitan Area, where a downtown rich in history coexists with a large scale residential new town. Despite its structural roots in classical TOD principles, its present urban form consists of weak linkages between the rail station centers and the peripheral regions of the city, separating spatial and travel behavior from critical urban functions. Considering the theoretical assumptions authors have made regarding the TOC, a corridor in Anyang has the potential to link the downtown and new town areas in linear form, combining efforts in transforming the urban spatial structure with strategies simultaneously regenerating the neglected areas in decline. With these circumstances, authors found Anyang to be a proper site for the analysis of expected results following the introduction of a TOC, specifically measuring and estimating the potential environmental and economic impacts in order to judge its effectiveness.

2. Transit-Oriented Corridor: Concept and Function

An alternative to auto-dependent urban spatial structures, TOC integrates bus and light-rail transit, such as trams, emphasizing local development of station areas. Unique from other TOD methods, it takes an existing principal transit line as its center and works to upgrade infrastructure. These systems are used in concert with mid-to-high density mixed-use buildings and pedestrian and bicycle pathways, thereby decreasing transfer resistance near transit stations and promoting more walking.

The greatest difference of TOC that can be specifically compared with TOD is as follows. TOC as compared to TOD that is planned and developed based on each station area is developed along the corridor, which is a way of linking each station area with a transit route as the center. Thus, while TOC differentiates roles and functions for each station area, it can maximize and modify the development potential of station areas in a city by linking and integrating functions with a transit route as the center. Above all, it is more effective than TOD in terms of efficiency of traffic network. In the case of Paris, the city developed 6 TOD-type station areas based on the intersection of 6 subways for reducing traffic congestion in the southern part of the city; however, there was no notable effect on reducing inveterate traffic congestion. Nevertheless, similar to the plan concept of TOC that is proposed in this study from the years 2003 to 2006, reorganization of streets for reducing twelve-lane roads to four-lane roads, instituting Tramway (T3) in the existing transit routes, expanding pedestrian roads and bikeways, and improving accessibility of mass transit in adjacent

Fig.1. TOD (top-left) vs. TOC (bottom-left) and TOC Planning Concept (Seo & Kim, 2012)
districts resulted in increasing transit ridership by twice, and decreasing traffic by 40–50%. The above cases are some of the proven data which enable the assertion that TOC can be more effective than existing TOD in terms of reduction of traffic in a city, and augmentation of utilization ratio of mass transit.

3. Literature Review

TOD is a comprehensive way to improve cities in terms of design, land use and space utilization. Kwon & Oh (2004) and Shin et al. (2007) discovered that station areas with large scale mixed-use facilities expanded mass transit use in the region and improved the pedestrian environment, by strengthening mixed-use integrated development. However, poor planning can negate such benefits. Sohn & Kim (2010) found that Seoul TOD station areas with car-friendly structures created adverse effects on pedestrian access and decreased the use of mass transit. Residential and commercial functions were not integrated properly, and nearby venues such as wedding halls and religious facilities suffered as higher rates of car use reduced the mass transit promotion effect of TOD by half.

On the other hand, TOC development is a more integrated and effective method of connecting transportation and land use, strengthening business promotion, integrating and differentiating clusters and creating synergy effects. In terms of urban spatial structure, TOC development creates transit links along a corridor, increasing ridership and promoting new land uses in the surrounding area. This results in decreased automobile use, reducing energy consumption and improving air quality in the corridor.

According to Caballero & Tsukamoto (2009), the centrality of Transit Urban Centers (TUCs) in Tokyo is formed in accordance with flows of people and mass transit, and public spaces were formed along streets as compared to other corporate urban centers. In addition, the boundary of TUCs is shown to be linear or fuzzy territoriality not dot-shaped. Also in terms of density, it is shown from small-sized to large-sized buildings, and mixed forms of commercial, residential, and public use in terms of land-use. Considering the above case study, existing TOD that conducts high-density development of large commercial buildings in a dot-shaped pattern around stations can be seen as a practical spatial structure with passages and functions are integrated with mass transit as the center. However, it is not reflected in Korea. On the contrary, a TOC that strengthens public space functions such as mass transit and pedestrian roads along the corridor, places the center of space development in a linear-shaped not dot-shaped pattern, and constructs corridors with mixed-use buildings in medium density can be more suitable than TOD in terms of spatial structure for carrying out functions of a transit urban center with regard to centrality, territoriality, density and land-use.

Today, cities are evaluated based on criteria of competitiveness, creativity and innovation in the cultural economy and how well these social phenomena are integrated depends on clustering (Scott, 1999). TOC development concentrates geographically dispersed urban activities into specific clusters, increasing the intensity and efficiency of urban space utilization. Porter (1998) observed how clusters of interconnected companies, specialized suppliers, service providers and related agencies within a geographically integrated area had a synergistic effect on the economy. TOC deployment practices in Denver and Boston have demonstrated that mass transit systems integrated with land use builds clusters with significantly increased utilization and greater tangible socioeconomic benefits compared to a generic TOD (CTOD, 2010).

At the district level, smaller blocks and more mixed-use buildings built along the TOD have been shown to increase occupancy times of floating populations, expand pedestrian volume and enhance commercial revitalization (Choi & Shin, 2001; Sohn & Kim, 2010). Also the revitalization of roads that link up with the mass transit route must all be given careful consideration in regards to the design of streetscapes, landscapes, aesthetics, and building height restrictions. TOCs can also play a role in the preservation of historic and cultural resources through landscape management planning. Working to coexist with the landscape and planning with various building types and ages in mind can further lead to the promotion of new development as a stronger sense of place improves brand identity.

Seo & Kim (2011) studied the effects of physical and spatial characteristics on Korean travel behavior related to density, diversity and spatial planning. They verified that travel choice, frequency and capacity were major factors, dependent upon reducing passenger car traffic and promoting effective urban mass transit to form a high net population. In the case of large metropolitan cities and their outlying areas, lower apartment housing density and road percentages were judged to be effective planning elements. Additionally, they found that within development areas, the mixing of retail, service and other industries followed an increase of mass transit use.

4. Methodology

4.1 Method

To analyze the environmental and economic impacts of our TOC planning model, authors measure and estimate both the relationship between TOC planning factors and transit modal share and the impact of transit accessibility on modal choice. Assuming that a hypothetical ridership increase would also increase pedestrian volume, authors next look at the impact on retail sales and perform an estimate of larger environmental and economic impacts in addition to changes in share of mass transit.
The planning elements of urban form have a close relationship with commuter behavior, and as Cervero & Kockelman (1997) noted in their study of the San Francisco Bay Area, the factors of density, diversity and design affect the use of mass transit. A variety of residential and employment facilities located in traffic circulation areas and a block structure that facilitates easy access to mass transit and destinations have been found to improve transit modal share (Ewing et al., 2008). Seo & Kim (2011) found in their study of the Seoul Metropolitan Region that net population, mixed zones of industry, and the proportion of car roads to mass transit shared statistically significant associations. To determine the relationship between TOC planning factors and transit modal share, authors synthesized prior research and assumed that the transit ridership ratio \( TR_t \) is the function of: the net population density of the TOC planning model \( NPD_t \), ratio of road \( RD_t \), mixing degree of retail and service \( MRS_t \) and the number of blocks per unit \( BU_t \):

\[
TR_t = f(NPD_t, RD_t, MRS_t, BU_t)
\]

**Impact of Accessibility on Transport Modal Choice**

TOC planning promotes mass transit ridership and strengthens mixed use through the improvement of the urban fabric. In other words, urban fabric built within the TOC should be involved in spatial organizational change. Authors wanted to analyze the impact that changes in the urban fabric would have on transit accessibility, which is expressed in the formula:

\[
V_i^n = constant_i + \beta_1 \cdot travel time + \beta_2 \cdot cost + \beta_3 \cdot access time + \ldots + \beta_k \cdot x_{k,i}
\]

\[
P_i^n = \exp(V_i^n) / \sum_{j=1}^{J} \exp(V_j^n)
\]

where \( n \) represents commuters, \( i \) transit mode, \( V_i^n \) utility for each transit mode, \( P_i^n \) the probability of each modal choice, \( x_{k,i} \) the property of the alternative transit mode, \( \beta_i \) the vector of point estimates, \( j(j=1,\ldots,J) \) represents alternative transit modes and \( k(1,\ldots,K) \) is defined as the number of properties. Walking time to access the mass transit stop is utilized as an additional variable. The following formulas define the utility functions for transportation modes:

\[
V_{auto}^n = constant_{auto} + \beta_1 \cdot travel time_{auto} + \beta_2 \cdot travel cost_{auto}
\]

\[
V_{transit}^n = constant_{transit} + \beta_1 \cdot travel time_{transit} + \beta_2 \cdot travel cost_{transit} + \beta_3 \cdot access time_{transit}
\]

**Impact of Pedestrian Volume on Retail Sales**

If access to mass transit is improved by upgrading the walking environment in the vicinity, (i) authors can assume that TOC can increase pedestrian volume in the surrounding area. Choi & Shin (2001) found that street pedestrians and consumers entering stores share a statistically close relationship, regardless of day or weather. Real estate evaluations often rely upon the international standard of revenue appraisal analysis and pedestrian volume is a major determinant. Thus, authors can assume that the number of consumers \( C_i \) is the function of volume of pedestrians \( P_i \) and that retail sales \( RS_i \) are a function of sales per consumer \( SC_i \) and number of consumers \( C_i \):

\[
RS_i = f(SC_i, C_i), \quad C_i = f(P_i)
\]

**Estimation of Environmental and Economic Impact of TOC Planning Scenarios on Transit Ridership**

Authors estimate the change in transit modal share and the environmental impact of transportation energy reduction by applying the scenario to the analytical model. Analysis suggests tram stations and the major arterial trunk itself are the most vital components. The integrated system will improve the urban fabric and strengthen mixed use to enhance functionality, bolster the net population, promote a mix of industries and alter both the ratio of roads and block unit areas. These scenario conditions are applied to the study model, and then the site is analyzed before and after introduction of TOC for changes in transit ridership, with an estimate of the resulting environmental impact from

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**Fig.2. Methodology of Environmental and Economic Impact of TOC**
Authors built a dataset from the 71 cities and districts of the Seoul Metropolitan Area to investigate the relationship between urban form and travel behavior at the macro level and Anyang was selected as the model site. The main factors analyzed were net population, mixed commercial and residential, and mixing of various industries, road ratio and modal share. A separate field survey focused on five station areas along a 9km stretch of arterial transit corridor covering an area of approximately 580ha. Detailed characteristics of 31 individual parcels of urban blocks were investigated for their configurations, use, and form. Using the combined statistical data, a digital map of a scale of 1:1000 was produced by ArcGIS.

Raw data was collected from relevant local government statistics and the '2006 Seoul Metropolitan Area Transit Conditions Survey.' To analyze TOC impacts on how mass transit usage would change and what economic impact it would have on the region, authors closely examined the 7,222 trip sample from Anyang which recorded trip purposes (commuting, shopping or leisure) and their choice of mode (pedestrian, car or mass transit), and isolated data from 1,057. Our field survey asked 89 commuters from the five station areas about transit facilities and accessibility for pedestrians. Additionally, another survey was carried out at 12 nearby street points observing pedestrian volume during weekdays/weekends, AM/PM rush hours and neighborhood retail sales with a total sampling of 72,613 pedestrians and 4,431 retail customers. Average consumer scale data was taken from the "2011 Convenience Store Operating Trends" report released by the Association of Korean Convenience Stores.

Table 1. Coefficients of Multiple Regression Model by Eq. 1

| Variables | Non-Standard | Standard | Error | Beta | t-value | Significance | Multicollinearity | Tolerance | Limit VIF | N/A | 1.123 | 1.182 | 1.302 |
|-----------|--------------|----------|-------|------|---------|-------------|-------------------|-----------|----------|------|-------|-------|-------|
| x1        | 0.571        | .026     | -.457 | .290 | 0.099   | .013         | 0.058            | .110      | 1.971   | .110 | .000  | .013  | .000  |
| x2        | 0.117        | 1.182    | .012  | .117 | 5.767   | 1.971        | 5.377            | 2.641     | 0.000   | 0.000 | .000  | .000  | .010  |
| x3        | 58.235       | .085     | .263  | .182 | 0.90    | .846         | 0.768            | .110      | 5.767   | .571 | .026  | .013  | .013  |

In order to determine the impact of the TOC on urban design, this study next looks at the relationship between the number of blocks per unit area and the ratio of transit ridership. A regression model was developed using each of the 31 administrative neighborhoods of Anyang, by combining the number of blocks per unit (BUi) and the ratio of transit ridership survey data (Eq. 2.). The adjusted R square (R²) was 0.414 and the Sig. F-statistic change (32.506) was 0.000. The results suggest that the number of blocks per unit area based on the level of traffic volume and the ratio of transit ridership share a statistically significant relationship. Specifically, the greater the number of blocks per unit area (in a smaller and more compact form), there is a tendency towards a greater ratio of transit ridership. For every increase in the number of city blocks per 'Δ' per hectare, the study found that ratio of transit ridership increased by 0.117ln(Δ) (Eq. 2.).

\[ y = 0.694 + 0.117\ln(x) \] (Eq. 2)

Table 2. Coefficients of Regression Model by Eq. 2

| Variables | Non-Standard | Standard | t-value | Probability |
|-----------|--------------|----------|---------|-------------|
| x1        | .694         | .012     | .000    | .000        |
| x2        | .643         | .020     | .048    | .010        |
| x3        | 5.701        | .000     | .013    | .000        |

**Probability Modal Choice Model by Accessibility**

Using the results of the transit modal choice estimation approach using a multinomial logit model, a probability modal choice model was developed utilizing data on commuters' accessibility to transit facilities, pedestrian traffic analysis and access distances to mass transit (Table 3.; Fig.3.).

\[ y = 0.571 + 0.026x_1 - 0.457x_2 + 0.290x_3 \] (Eq. 1)
First, if the estimated travel time ($\beta_1$) and the travel cost ($\beta_2$) is negative and has a significance level of 1-5%, then it is estimated with statistical significance that a decrease in travel time lowers the cost of the corresponding transport mode. If transit access time ($\beta_3$) has a negative significance level of less than 1%, then it is estimated with statistical significance that shorter access time derived preferred results, invalidating the model.

**Impact Estimate Model of Pedestrian Volume on Retail Sales**

Having shown that improved access to mass transit increases pedestrian volume, authors can estimate TOC impacts on retail sales. The analysis of variables considered the volume of pedestrians ($P$) and number of consumers ($C$) and applied it to the annual sales per consumers ($SC$) survey data of the Association of Convenience Stores. The analysis covered 12 areas during weekdays, weekends, AM/PM and peak walking hours for a period of one week. The results of the field investigation found that of 72,613 pedestrians, 4,431 were customers entering stores, with the resulting estimation model (Eq. 3; Table 5). The adjusted R square ($R^2$) of Eq. 3 was 0.802, and the F-statistic change 185.985 with a Sig. F-statistic corresponding transport mode. If transit access time ($\beta_3$) has a negative significance level of less than 1%, then it is estimated with statistical significance that shorter access time derived preferred results, invalidating the model.

**5.2 Empirical Results**

**Application of the TOC Planning Model**

To analyze what type of transit/environmental impact occurs, the following is an empirical analysis of the target area applied along with the TOC planning model. Specifically, the TOC impacted area is of a moderate scale, large city blocks measuring 1.5 to 2.5ha were divided into smaller ones of under 1.5ha. Within a 200m radius of the axis, mixed-use development strengthens the area with public and mixed residential-commercial buildings. Residential buildings were placed in parcels within the 200 to 400m radius of the TOC axis. Redevelopment was carried out with relative ease for a second round of dwelling areas, with a portion for eight- to twelve-story buildings and parceling unit lots into scaled deployments of additional multi-family housing at higher building density and floor area ratio.

Roadways parallel to the corridor were reduced by one lane in order to construct the tramway, while pedestrian footpaths on each side were widened, reducing the total number of dedicated car lanes to two or three. The TOC-centered transit system would pass along a 9km stretch encompassing Induewon, Pyoungchon, Bumgye, Myunghak and Anyang stations. The tram stops in intervals of 400 to 500m, each additionally linked to existing bus stops, creating a total of 17 commuter access points to transit. It can be assumed that this study's TOC planning model could produce two potential scenarios. In the first, the target area will experience increases in population density of 7% and rate of industry mixing at 2.8%, a reduction in ratio of road by 1.1%, and a higher number of blocks per unit area from 0.448 to 0.777 per ha. The second scenario maintains the same planning elements of the first, but expands residential areas and introduces other enhancements in the use and function of mixed residential and commercial areas, increasing the net population density by 15% and rate of industry mixing by 6.7% from its current state (Table 6.).

**TOC Environmental and Economic Impact**

Analyzing each scenario of the TOC planning

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### Table 3. Multinomial Logit Model of Probability Modal Choice

| Variables (x_i) | Cumulative distribution ratio (%) |
|-----------------|-----------------------------------|
| Estimation Coefficient | t-value |
| Constant | Walk | 5.409 | 2.506* |
| Auto | -3.548 | -6.387** |
| Travel time ($\beta_1$, min) | -0.181 | -3.658** |
| Travel cost ($\beta_2$, 1000 won) | -0.274 | -2.199** |
| Transit access time ($\beta_3$, min) | -0.447 | -14.685** |

Sample size: 1,057

### Table 4. Coefficients of Regression Model by Eq. 3

| Variables | x | Non-Standard Coefficients | Standard Error | Standard Coefficient | t-value | Probability |
|-----------|---|---------------------------|----------------|----------------------|---------|-------------|
| x | B | .062 | .005 | Beta | .895 | 13.638 | .000 |

### Table 5. Field Survey Result of Pedestrians and Consumers

| Weekday (12:00-13:00) | Weekday (18:00-19:00) | Weekend (12:00-13:00) | Weekend (18:00-19:00) |
|------------------------|-----------------------|-----------------------|-----------------------|
| P | C | P | C | P | C | P | C |
| A | 524 | 22 | 576 | 39 | 1410 | 94 | 2166 | 151 |
| B | 568 | 32 | 524 | 41 | 1675 | 96 | 2190 | 109 |
| C | 259 | 29 | 393 | 18 | 1061 | 54 | 1118 | 41 |
| D | 378 | 76 | 554 | 63 | 1285 | 90 | 1358 | 79 |
| E | 892 | 64 | 1023 | 64 | 1958 | 141 | 1846 | 169 |
| F | 706 | 33 | 906 | 46 | 1882 | 123 | 2030 | 107 |
| G | 2116 | 134 | 2212 | 111 | 2108 | 134 | 2032 | 127 |
| H | 1824 | 121 | 2092 | 143 | 1964 | 133 | 1680 | 129 |
| I | 2469 | 110 | 2875 | 163 | 2879 | 196 | 3478 | 249 |
| J | 1946 | 103 | 2147 | 162 | 1988 | 126 | 1762 | 88 |
| K | 1208 | 69 | 1444 | 36 | 1420 | 92 | 2092 | 81 |
| L | 618 | 22 | 722 | 48 | 963 | 19 | 1292 | 54 |

* P means to number of Pedestrian and C means to number of consumer.
model, it was found that its application to Anyang would make a significant contribution to realizing the benefits associated with green cities. Specifically, the planning elements of industrial mixed-use and number of blocks per units help facilitate improvement in the ridership ratio. In this particular scenario, an increase in the mixture of industries in the range of 2.8 to 6.7% would result in a ridership ratio increase of 0.8 to 1.9%. Throughout the 15 administrative neighborhoods within the TOC effect area in Anyang, transit ridership ratio is estimated to rise by 7.4 to 12.1%. In addition to the ridership ratio increase, in the vicinity of the TOC, the average daily pedestrian volume is estimated to rise by 28,526 to 52,724 (Table 7).

If authors were to look at the hypothetical environmental and economic impact the TOC would have on Anyang as a whole, introducing a 9km TOC extending from downtown to the new town district, the ridership ratio is expected to increase by 3.5 to 5.9%. The decreased road traffic would reduce transportation energy consumption by 156 to 275 thousand kl and CO₂ emissions by 391 to 686 thousand tons (TOE). Economic benefits resulting from the reduction in annual CO₂ emissions are estimated to be in the range of 226 to 397 million dollars. Assuming that additional housing supply is built for a larger resident population using mass transit as pedestrian accessibility increases within the TOC area, annual income for neighborhood retailers would increase in the range of 7.4 to 13.6 million dollars.

6. Conclusion

In this study, the following results and implications can be drawn from traffic, environmental and economic impact analysis of the established TOC model and probability of modal choice of transit.

Firstly, in order to promote increased use of mass transit within the transit area, more mixed-use space would be needed to highlight the city's residential and commercial features, along with a lower ratio of urban roads. This is consistent with Lim's (2007) survey findings of 177 TOD-type neighborhoods in Seoul. As a result of this study, in the case of Anyang, if the mixture of industries related to wholesale and retail within a 600m radius of a transit route increases from the current 31.4% to 38.1% by constructing TOC, and decreases the road ratio of 17.7% to 16.6%, it is assumed that transit ridership will increase 2.0% more than at present. Thus, it is necessary to compose street spaces with low road ratio and mixed-use buildings of surrounding transit corridors for urban development by utilizing transit hereafter.

Secondly, the results of the transit modal choice analysis revealed that accessibility to transit was an important variable in determining its usage. In the case of Anyang, the majority who live within 5-15 minutes walking distance to transit facilities used it to travel within city limits. Specifically, the result of this study concerning the probability of modal choice of transit in Anyang shows that of people whose residences are located within a 10-minute walk from subway stations

Table 6. Application of TOC in Anyang: Before and After

| Before application of TOC planning model | After application of TOC planning model |
|----------------------------------------|---------------------------------------|
| Urban Spatial Structure                |                                       |
| District Condition                     |                                       |
| Accessibility Mass Transit             |                                       |

Following the introduction of the TOC, additional necessary use and size adjustments for surrounding buildings was color coded; red for commercial, orange for mixed-use, and grey for preservation. The green line represents the tram and pedestrian mall.
or bus stops, 53% travel 6.4km further, and 92% travel 8.6km further to use transit. Therefore, it is concluded that forwarding policy of providing public housing within transit corridors for low-income people who depend more on transit is effective just as Handy (2005) identified the basic principles of smart growth.

Lastly, the study simulated the impacts by assuming that instituting TOC that plans to construct a tramway and reducing the number of lanes on roads, surrounding 400m of residential density and mixture of industrial development as one package for a transit corridor which connects existing TOD-type 5 station areas in Anyang. As a result, TOC was analyzed as it can improve effects in terms of transportation and environment of TOD, specifically, the mass transit shifting ratio increases 3.5–5.9%, carbon emission decreases by 40.2–73.1 million tons yearly, the economic effect in accordance with low-carbon and market revitalization is estimated as 233.4–410.7 million dollars yearly with respect to the scenario. Thus, in the case of cities with incomplete efficacy of low-carbon and decrease of vehicles through instituting TOD, it is necessary to consider TOC as an alternative, which integrates land-use and transportation development along the transit corridor, and builds a walking and transit friendly urban environment along the transit corridor.

In the actual process, stakeholder conflicts will likely occur and delay the work, so a further follow up study is needed to examine, analyze and review issues of governance to bring about the best possible outcome.

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References

1) Caballero, J. and Tsukamoto, Y. (2009) Tokyo Public Space Networks at the Intersection of the Commercial and the Domestic Realms. Journal of Asian Architecture and Building Engineering, 8 (2), pp.461-468.
2) Cervero, R. and Murakami, J. (2009) Rail and Property Development in Hong Kong. Urban Studies, 46 (10), pp.2019-2043.
3) Cervero, R. and Kockelman, K. (1997) Travel demand and the 3Ds: Diversity, Density, and Design. Transportation Research: D. 2(3), pp.119-219.
4) Choi, M. and Shin, S. (2001) An Empirical Analysis of the Effect of Pedestrian Volume on Retail Sales. Journal of Korea Planners Association, 36(2), pp.75-83.
5) CTOD (Center for Transit-Oriented Development) (2010) Performance-based Transit-Oriented Development Typology Guidebook. Washington DC: Federal Transit Administration.
6) Ewing, R. et al. (2008) Growing Cooler: the evidence on urban development and climate change. Washington DC: Urban Land Institute.
7) Gore, A. (2006) An Inconvenient Truth: The Planetary Emergency of Global Warming and What We Can Do About It. New York: Rodale Books.
8) Handy, S. (2005) Smart Growth and the Transportation-Land Use Connection: What Does the Research Tell Us? International Regional Science Review, 28(2), pp.146-167.
9) Kwon, Y. and Oh, J. (2004) Transit-Oriented Urban Development and Transportation System. Goyang: The Korea Transport Institute.
10) Lim, H. (2007) Developing Transit-Supportive Neighborhood Model in Seoul. Seoul: Seoul Development Institute.
11) Porter, M. (1990) The Competitive Advantage of Nations. 1st ed. New York: Free Press.
12) Scott, A. (1999) Regions and the World Economy: The Coming Shape of Global Production, Competition, and Political Order. 1st ed. New York: Oxford University Press.
13) Seo, M. and Kim, S. (2011) An Analysis on the Relationship between Planning Elements of Urban Form and Travel Behavior Characteristics. Journal of Korea Planners Association, 46(4), pp.223-244.
14) Seo, M. and Kim, S. (2012) The Impacts of Transit-Oriented Corridors on Realizing the Green City. Journal of Urban Design Institute of Korea. 13(1), pp.93-109.
15) Seo, M. et al. (2011) Planning of the Transit-Oriented Corridor towards Green City Development. Anyang: The Korea Research Institute of Human Settlements.
16) Sohn, D. and Kim, J. (2010) Analysis of the Relationships between Land Use Characteristics of Urban Transit Centers and the Level of Transit Usage. Journal of Urban Design Institute of Korea. 11(1), pp.33-44.
17) Song, K. and Nam, J. (2009) An Analysis on the Effects of Compact City Characteristics on Transportation Energy Consumption. Journal of Korea Planners Association, 44(5), pp.193-206.
18) Sung, H., Park, J. and Kim, D. (2007) Impact Analysis of Transit-Oriented Development and Revising Current Transportation and Urban Planning Laws for its Application in Korea. Goyang: The Korea Transport Institute.