

## **Potentials and Challenges for Using the Clean Development Mechanism for Transport-Efficient Development: A Case Study of Nanchang, China**

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## ABSTRACT

We propose a methodology, consistent with the Kyoto Protocol's Clean Development Mechanism (CDM), to quantify the greenhouse gas (GHG) emission reduction benefits of transport efficient development (TED). The TED concept aims to reduce transportation GHGs via interventions in urban development patterns. We use the Nanchang Transit-Oriented Development project in China to demonstrate the methodological approach and, thus, the possibilities for bringing such projects into the carbon market. The case illustrates the opportunities for and challenges to using the CDM to reduce transportation GHG emissions by changing urban development patterns. While theoretically promising, utilizing the CDM for TED involves important methodological challenges. The proposed analytical approach, utilizing a "control group," faces difficulties regarding geographical control, the reliability of the statistical techniques, and challenges to calculating emissions "leakage." These methodological difficulties also impact financial viability because of high monitoring costs and high project risks.

## INTRODUCTION

Transportation currently accounts for one-quarter of the world's energy-related carbon dioxide (CO<sub>2</sub>) emissions and is expected to be the most rapidly growing source over the next 30 years, increasing at an annual rate of 2% to 3% (1). The developing world will account for the largest share of this growth, with forecasted growth rates between 3.5% and 5.3% per year, as compared to 1.2% to 1.4% in the OECD. Given these forecasts, the developing world will shift from accounting for roughly 35% of world transportation greenhouse gas (GHG) emissions in 2000 to 52% to 63% by the year 2030 (1).

To modify these emission growth trajectories, we will likely need a suite of technology, policy and pricing approaches, focusing on both passenger and freight transportation at both the urban and inter-urban levels. In the short- to medium-term, technological fixes alone will most likely not provide the hoped-for "silver bullet." Heywood et al (2) provide a sense of the challenges; their assessment of plausible vehicle technological improvements in the U.S. private passenger vehicle market leads them to the "sobering overall conclusion" that technology *and* demand management options – i.e., *behaviorally*-based interventions – together will be required.

In this context, we cannot ignore passenger transport: personal mobility consumes roughly two-thirds of transportation energy today, a share expected to remain fairly stable over the next 50 years (3). Nor can we ignore the developing world's metropolitan areas, where population will double by 2030, representing 95% of net global population growth, or 1.94 billion additional people (4). Changing passenger travel behavior in urban areas of the developing world may be crucial to reducing long run transport GHG emissions.

Perhaps no developing country better represents the challenges and opportunities for reducing urban transportation GHG emissions than China. The country is undergoing a major demographic transition of rapid and intense urbanization, coupled with sustained economic growth, and changes in consumer behavior and industrial and economic activity. While China already has more than 100 cities with 1 million or more persons, just 40% of its total population currently lives in urban areas – this share will increase to 60% by 2030 (4). At the same time, motorization continues apace; the country is already the world's fourth largest automobile producer and the third largest consumer. In this decade, car sales have been growing by 70% per year.

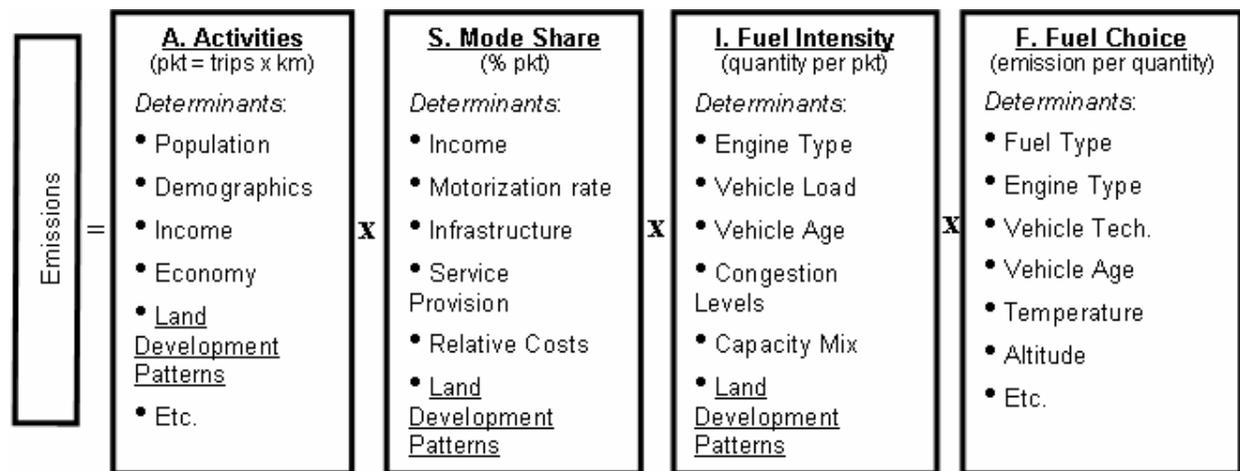
These forces – combined with economic reforms, fiscal decentralization, and changing consumer expectations with respect to, e.g., residential space – are dramatically transforming China's urban landscape. For example, during the 1990s Shanghai's population density declined by 50%. While necessary as cities modernize and business and residential space demands increase, these transformations raise the question: how can we capitalize on the dynamism of urban China to create more energy efficient cities? Specifically, to what degree can alternative future urban development patterns change travel behavior to help move China towards a less energy-intensive urban transportation future? Can the current carbon market play a meaningful role in inducing such changes? To help answer these questions, we

outline a methodology for quantifying the transportation GHG reduction benefits of an urban land development project, using a specific project in Nanchang China for illustration.

## THE POTENTIAL ROLE OF THE BUILT ENVIRONMENT

Interest in modifying urban development patterns to influence transportation energy consumption, emissions, and travel behavior has a long history. We can find urban simulation models of “hypothetical cities” in the 1960s (e.g., 5); numerous more recent regional travel modeling applications to actual cities (e.g., 6); empirical analyses attempting to quantify the built environment’s influence on travel behavior (e.g., 7); and policies and projects that have taken various approaches to try to leverage the built environment-travel behavior relationship (e.g., 8, 9).

Schipper et al’s “ASIF” framework (10) provides a way to understand the components contributing to transportation energy use and emissions. The ASIF optic reveals the essential determinants of transportation energy use: total activity (A), mode share (S), fuel intensity (I), and fuel type (F) (thus, ASIF) (see Figure 1). Land development patterns potentially influence three of the four components (activities, mode share, and fuel intensity), since urban size, form, density, land use mix, and design (including street patterns) may affect the distribution of activities and total travel distances (e.g.,11), mode choice (e.g.,12), and vehicle occupancy (e.g.,13).



**FIGURE 1 ASIF: Determinants of Urban Passenger Transportation Energy Use/GHG Emissions (14)**  
 Note: pkt = passenger kilometers traveled.

In the following methodology, we propose the generic concept of transport efficient development (TED), which encompasses a range of investments and policies which attempt to improve transport efficiency through land development. The TED idea builds upon the ideas popularized under the term Transit Oriented Development (TOD) – integrating land development with public transportation by concentrating dense, mixed-use, and pedestrian-friendly urban “nodes” around public transportation stations. Extending on TOD, TED includes:

- A transit-oriented development density gradient – increasing the number of persons and activities close to transit stations, the attractiveness of public transit relative to driving, and transit ridership and efficiency;
- Mixed land use – decreasing distances between destinations thereby shortening average travel distance and making non-motorized transport (NMT) more attractive;
- Dense and well-connected road/transit network – reducing travel distances and increasing the attractiveness of NMT and public transport;
- Pedestrian- and NMT-friendly facility and urban design – making NMT more attractive;

- Self-sustained community services – reducing travel distance for certain trip purposes, reducing vehicle distances traveled, and increasing attractiveness of NMT;
- Car use restrictions, efficient parking management, traffic calming, etc. – making driving relatively less attractive, thereby inducing shifts to less GHG-intensive modes.

Despite its intuitive appeal, using TED to modify travel behavior faces numerous institutional, financial and other challenges. In addition, when aiming to understand the potential travel behavior effects of land development interventions, we face a number of analytical challenges, including lack of adequate data, modeling complexity, etc.

### **Analytical Challenges**

One important theoretical and empirical challenge in understanding the built environment's role in transport GHGs relates to the issue generally referred to as "self-selection" (see (15) for a good review of the issues and relevant analytical approaches). In this specific context, "self-selection" arises because, in using comparative analyses of individuals' behavior (e.g., residents in a TED versus residents in a non-TED) to determine the built environment's influence on travel, we may incorrectly attribute the outcome (behavior) to the supposed cause (built environment). By using observed outcomes and characteristics, our attempt to infer causality from the built environment to travel behavior may be confounded by other unobserved characteristics – such as individuals' attitudes towards or preferences – which may be responsible for at least part of the travel outcome. In the TED case, for example, some residents living in the project area may have chosen to move there because the TED allows them to more easily travel how they would have traveled anyway (e.g., by certain modes). Considerable research in recent years has attempted to control for, and understand the impacts of, self-selection in the built environment-travel behavior realm (as summarized in 15). Most studies do detect self-selection, although few explicitly quantify the relative influence. A recent analysis of residential choice, vehicle ownership choice, and walking levels in New York City estimates that self-selection accounts for one-third to one-half of the estimated influence of the built environment (measured as population density) on walking levels (16). Note that self-selection presents a challenge in comparative analyses (e.g., TED versus non-TED) as well as in simulations/forecasts of future conditions since parameters in the latter should be based on observed behaviors which might be biased from self-selection.

We cannot ignore this issue when attempting to finance TED projects via the carbon market, for which emissions must be quantifiable, verifiable, and additional to business as usual (i.e., beyond what would have occurred without the project). By ignoring self-selection we run the risk of falsely crediting TED for GHG emissions reductions, thus incorrectly granting carbon credits and, effectively, "robbing" climate value. Thus, bringing TED-type projects into the carbon market forces an analytical rigor with respect to adequately measuring relevant behaviors, isolating potentially confounding influences, and properly inferring causality.

### **The Clean Development Mechanism and Transportation**

Currently, the Kyoto Protocol's Clean Development Mechanism (CDM) is the main market-based instrument for mitigating GHG emissions in the developing world. The CDM has the explicit dual purpose of providing industrialized countries with the opportunity to achieve cost-effective emissions reductions while also contributing towards developing countries' sustainable development goals. The latter are sometimes referred to as "co-benefits," or "the benefits from policy options implemented for various reasons at the same time – including climate change mitigation" (17). Via the CDM the industrialized country project "proponent" earns Certified Emission Reduction units (CERs). The market value of a CER varies according to the prevailing carbon price and can be influenced by risk factors; future (2010) CER prices are US\$32 (25 Euros in November 2008), representing a 30% risk spread relative to carbon offsets generated in Europe.

To date the CDM has proved difficult to apply to the transportation sector. As of July 2008, the transportation sector accounts for just two of the 1,359 registered CDM projects worldwide: phase II and

following of the *Transmilenio* bus rapid transit (BRT) project in Bogotá, Colombia, with emissions reductions due primarily to reduction of the bus fleet and increased bus loading factors; and, the installation of energy-efficient rolling stock in the Delhi Metro Rail Corporation in India (18). The sector itself poses important CDM challenges, in part due to its dispersed emissions sources (i.e., individual vehicles) with few readily available, less carbon-intensive energy substitutes. An analysis of CDM possibilities for Santiago's (Chile) transportation system (14) suggests that technology switches (introduction of hybrid-diesel buses) seem attractive within the CDM framework, while behaviorally-oriented interventions (promoting bicycle use, changing urban development patterns) face considerable challenges, including establishing a defensible baseline against which project impacts can be monitored and verified. This also implies a possible conflict between the CDM's ostensible dual purposes: reducing GHGs and producing "co-benefits."

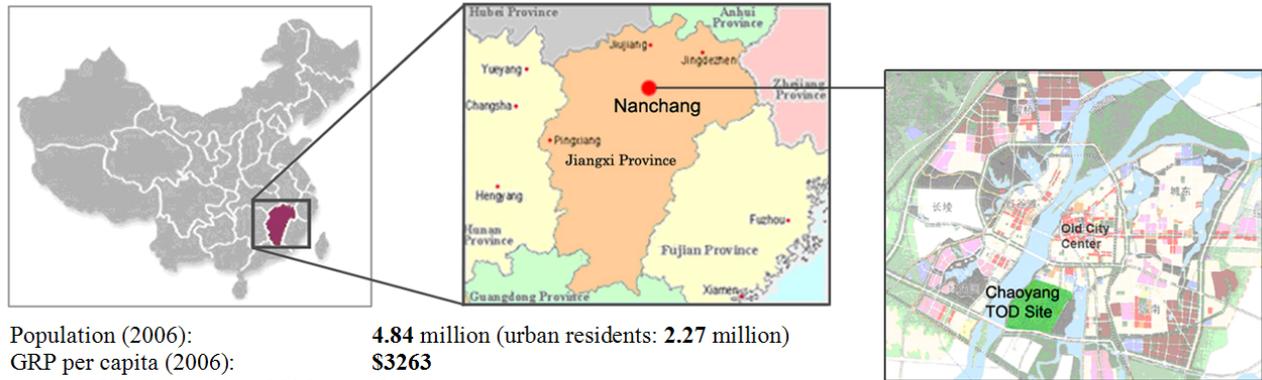
The Santiago transport CDM analysis included a detailed effort to analyze potential land use interventions, via integrated land use-transportation modeling (19). The approach estimated the financial costs implied by re-orienting urban development patterns relative to the status quo and compared those costs to possible financial flows from carbon offsets (due to GHG reductions). The approach demonstrated long-term carbon market potential and, via the integrated modeling, accounted for potentially unintended consequences, such as the impacts of development in one area on other parts of the city. The approach does not, however, obviate the need for effective monitoring and verification, which could be at the "macro level" – e.g., monitoring fuel consumption in the city – or at the "micro level" – e.g., surveying household (and firm) behavior in time. In the latter case, control for "self-selection" would still be necessary.

### **THE CASE OF NANCHANG, CHINA**

Nanchang, the capital city of Jiangxi Province, has over 2 million urban residents. In 2005, non-motorized transport (NMT) still accounted for more than 60% of all trips (see Figure 2 for more statistics). The city government has proposed to redevelop its Chaoyang South District using TOD concepts. As part of an application for funding from the Global Environment Facility (20), the Nanchang TOD plan has following objectives:

- Accommodate the city's economic and population growth;
- Meet residents' increasing travel demand without causing additional traffic congestion;
- Promote sustainable land use planning in terms of energy consumption and emissions;
- Reduce the average travel time per passenger trip;
- Improve the urban environment;
- Pilot sustainable transportation strategies for other inland Chinese cities.

Major components of the Nanchang TOD project include a dense bus network and mixed-use land development with focus around major bus stops. The public sector will completely fund the Nanchang TOD project. The estimated construction costs total 0.565 billion Yuan (US\$81 million in November 2008), for which the World Bank proposes a loan of 0.392 billion Yuan (US\$56 million in November 2008), with the remaining financed through the local government (21).



Population (2006):	4.84 million (urban residents: 2.27 million)
GRP per capita (2006):	\$3263
Average Household Size (2006):	2.61
Per capita Income (2006):	11905 yuan (\$1587)
Bus Fleet (2007):	2127 vehicles
Bus Lines (2007):	121 lines
Bus Fare (2007):	1 yuan except airport shuttle (10 yuan), double-deck buses (1.5 yuan)
Number of Taxis:	3569
Car Ownership (2005*):	59 cars/ 1000 household
Trip Rate (2005*):	2.56 trips per day per person

Mode (2005*)	Walking	Biking	Transit	Taxi	Motorcycle	Company Vehicle	Private Car	Truck	Electric Bike	Other
percentage	39.29	23.83	13.70	1.60	5.94	2.02	2.83	0.22	9.95	0.61

\* Data summarized from household travel survey conducted in 2005. However, the transportation condition has changed a lot since 2005: e.g. according to Nanchang Bureau of Planning, congestion became an issue after 2005; according to author's field trip observation and rough count, motorcycle and electric bikes are at least twice as many as bicycles on roads.

**FIGURE 2 Location and Basic Statistics of Nanchang, China (22)**

### Emission Reduction Potentials of Land Development

Integrated policies which realize travel behavioral change could help move China towards an energy-efficient and less emission-intensive future. As an example, a 2004 analysis (23) presented three different scenarios of future automobile energy use in China. Under business as usual (BAU), auto energy use will increase by nearly 12 times over the 2003-2020 period. A scenario of usage pricing and aggressive introduction of alternative-fueled vehicles reduces automobile energy demand by one-half, relative to BAU, by 2020. A more ambitious scenario, building on the latter to include travel behavior-based measures including land use management, would reduce automobile energy demand to just one-fifth of baseline 2020 levels. Intervening now in Chinese urban development patterns offers the potential to change urban growth trajectories and associated travel demand. Failure to intervene threatens to lock the country's cities into a heavily energy-dependent transportation future and may hamper future urban productivity (24).

In theory, TED would reduce GHG emissions through short-term travel behavioral change and long-term lifestyle change. In the short term, Nanchang TOD measures might impact, via various paths, trip distance, mode choice, and vehicle occupancy (see Table 1). In the long run, lifestyle changes, including attitudes towards different modes (e.g., better image of NMT) and slower growth of car ownership (as driving becomes relatively less attractive), further influence travel behaviors and reinforce TED patterns. In this context, TED has great theoretical CDM attraction because of: 1) long-term emission reduction potential through changing travel behaviors and lifestyles; 2) potential sustainable development "co-benefits."

Note that only "additional" emission reductions produced by TED would qualify for the CDM; i.e., under the current interpretation of the relevant rules, the project cannot have occurred in absence of

the CDM. Although the government has already proposed the TOD project, current urban development patterns in China may still impose certain barriers which allow the project to meet the additionality requirement. The CDM Executive Board's Tool for the Demonstration and Assessment of Additionality (25) outlines how barrier analysis and common practice analysis could be used to justify additionality. We identify four important barriers to the proposed Nanchang TOD project that the CDM could at least partially help overcome.

**TABLE 1 Nanchang TOD Measures and Potential Impacts on Emission Reduction**

TOD Measures	Potential Impacts
<b>Balanced/mixed land use</b> <ul style="list-style-type: none"> <li>- job-housing balance</li> <li>- shopping, entertainment, hospital, and schools</li> <li>- adequate community amenities</li> </ul>	<ul style="list-style-type: none"> <li>- <b>Shorter trips</b> (some long trips to the city centre become shorter as activity centers and trip generators are closer)</li> <li>- <b>Mode switch</b> (some change from car and buses to NMT because as trip length gets shorter, NMT becomes more attractive)</li> </ul>
<b>Focus urban development along bus corridors and around major bus-stop</b>	<ul style="list-style-type: none"> <li>- <b>Mode switch</b> (from other modes to buses as the distance to bus stops gets shorter so time cost of using buses decreases therefore buses become more attractive)</li> <li>- <b>Vehicle occupancy</b> (increasing bus loading factors)</li> </ul>
<b>Car use restriction</b> <ul style="list-style-type: none"> <li>- peak hour detour</li> </ul>	<ul style="list-style-type: none"> <li>- <b>Longer trips</b> (car trips get potentially longer because cars have to detour during peak hour)</li> <li>- <b>Mode switch</b> (car to other modes at peak hour because the time cost of using cars increases and cars become less attractive)</li> <li>- <b>Vehicle Occupancy</b> (car-pooling become more attractive and bus loadings may increase)</li> </ul>
<b>Transit Improvement</b> <ul style="list-style-type: none"> <li>- more transit lines and stops</li> <li>- more bus parking</li> <li>- improved bus stations</li> </ul>	<ul style="list-style-type: none"> <li>- <b>Improve mode efficiency</b> of bus fleet</li> <li>- <b>Mode switch</b> (from other modes to buses, as the time cost of taking bus decreases and convenience increases therefore buses become more attractive )</li> <li>- <b>Vehicle Occupancy</b> (increases for buses)</li> </ul>
<b>Improve the quality of bus connections between the development/redevelopment district and the city centre</b>	<ul style="list-style-type: none"> <li>- <b>Shorter trips</b> (bus trips can be shorter because of better connection)</li> <li>- <b>Less congestion</b> (city overall congestion will be less as the network is more efficient)</li> <li>- <b>Vehicle Occupancy</b> (increases for buses)</li> </ul>
<b>NMT/pedestrian parkway</b>	<ul style="list-style-type: none"> <li>- <b>More trips</b> (people might want to take more NMT trips for entertainment)</li> <li>- <b>Mode switch</b> (other modes to NMT and buses)</li> </ul>
<b>A road network with public transit and NMT priorities</b>	<ul style="list-style-type: none"> <li>- <b>Mode switch</b> (other modes to NMT and buses)</li> </ul>
<b>Pedestrian/bike friendly urban design</b>	<ul style="list-style-type: none"> <li>- <b>Mode switch</b> (other modes to NMT and buses)</li> </ul>

### *1. Financial/investment barrier*

Perhaps paradoxically, the City of Nanchang risks a lower potential land lease price with the TOD. In China, the perception of public transit as a mode for low-income people and the unproven TOD market might make the project less attractive to developers. This might produce a lower than expected bid price for the development land, especially at the beginning of the project. For example, officials from the Bureau of Land Resources and Construction Committee voiced concerns that lower land lease bids would result in an extra financial burden on the city. CDM revenues could at least partially offset the reduced revenues and thus reduce this political disincentive.

### *2. Prevailing practice barrier*

Very few TOD projects, especially with buses as major transit systems, have been implemented for new development/redevelopment projects in Chinese cities. The South Chaoyang TOD project would

be Nanchang's first, and also represents the first TOD project based on buses among inland cities in China. Thus, the unprecedented Nanchang TOD signifies a risk. The knowledge, experience, and power of example brought by the CDM process would help reduce this prevailing practice barrier and accumulate TOD know-how and implementation experience for Chinese cities.

### *3. Lack of know how and experience*

Planning agencies and other government decision makers in Nanchang, as well more generally in China, lack familiarity with TOD concepts and benefits and lack implementation experience. This knowledge gap relates to the lack of existing TOD examples in China. A CDM-based project raises the chance for building TOD implementation capacity.

### *4. Political Resistance and Risk of Incomplete Implementation*

TOD projects typically require long term investments, realized in phases, producing long-term benefits. Such projects risk abandonment if no immediate and measurable returns are achieved. Successfully implemented measures would produce a constant income flow from CERs, possibly providing an incentive to sustain TOD measures. The monitoring required for a CDM project also enables the quantification of TOD impacts, which may be important for sustaining and expanding TOD concepts and providing a basis for replication elsewhere. This would complement recent Chinese central government initiatives to promote "energy-saving" and "emission-reduction," now included as evaluation criteria for local government officials. A registered CDM project would be considered a showcase, providing political dividends for local officials and helping to reduce political barriers.

## **PROPOSED METHODOLOGY**

### **Challenges**

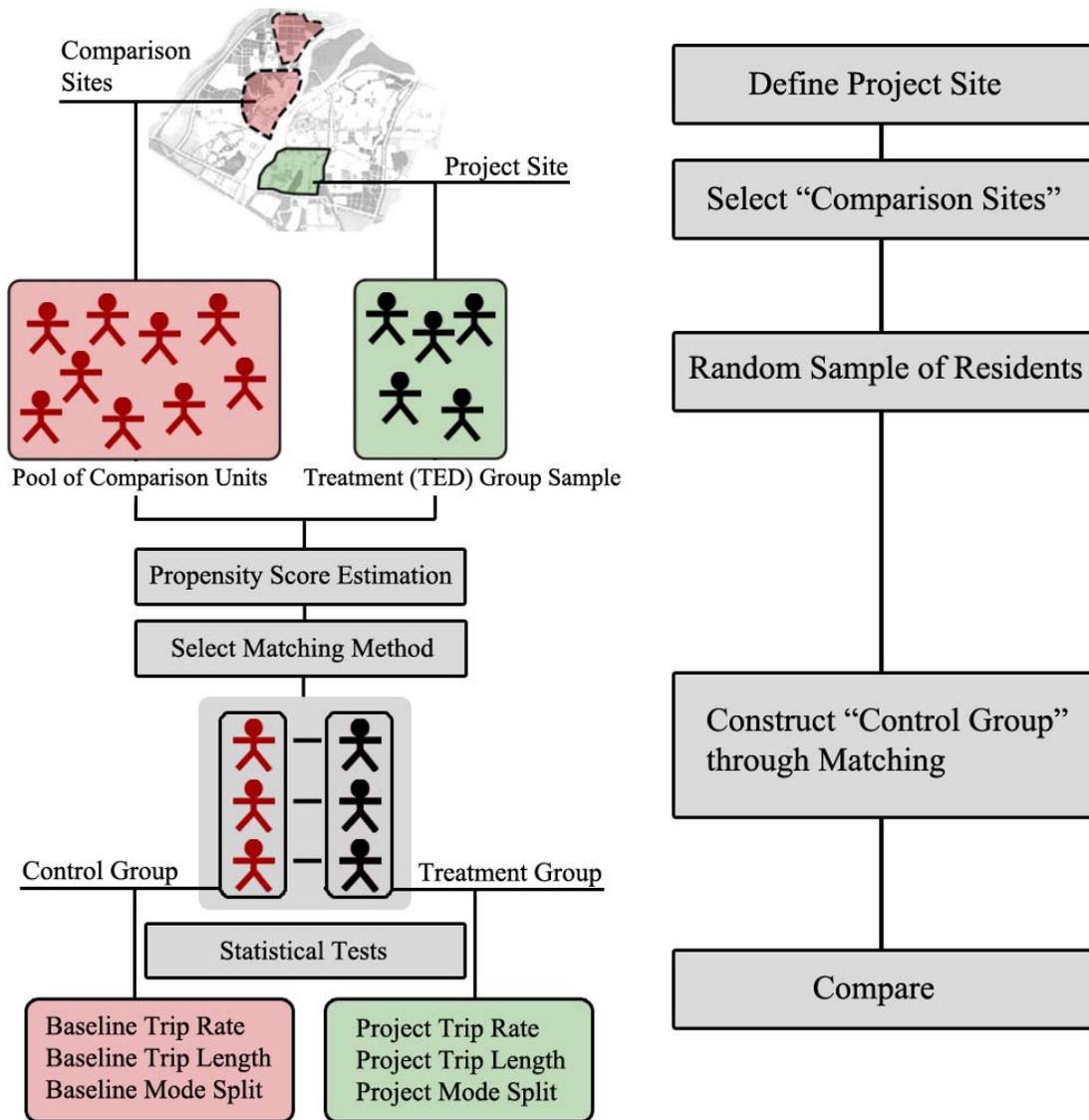
Despite its promise, TED faces a host of CDM-related challenges. As mentioned above, the CDM forces a rigorous examination of the hypothesized causality between the built environment and travel behavior. However, this requirement and uncertainty regarding the magnitude of emissions reductions imply high transaction costs and relatively high project risks. In the CDM framework, projects targeting behavioral changes (of which there are few, if any, successful CDM projects to date) face some fundamental, inter-related challenges. First, we have potential "leakage" – basically, the possibility that a project merely shifts emissions from one place (or activity) to another. At the broadest level in the carbon offset arena, leakage represents the proverbial "elephant in the room." For example, a project (in any sector) which improves energy efficiency (thereby reducing operating costs) could result in increased total economic activity and net GHG emissions. In the transportation sector, if we want to maintain true climate fidelity, we need to account for the possibility that, for example, a project that reduces transportation costs might increase travel demand (the so-called "rebound effect"). The "rebound effect" extends beyond the urban travel market; if we consider potentially constant average travel budgets (time and income share) (e.g., 26), the possibility exists that people might "re-invest" their urban travel time and money savings due to, say, living in a TED into more long-distance travel, including by highly GHG-intensive modes.

A second challenge comes from the need to establish defensible baseline emissions – those which would have resulted in the project area under prevailing land development patterns. We cannot observe a counterfactual in this case (i.e., we cannot see how the city would have looked and operated without the project). The use of travel forecasting models seems subject to strong and reasonable criticisms; research has shown their results can vary widely depending on the specific model used (e.g., 6). Furthermore, in contexts of intense dynamism *and* poor data availability, reliable use of such models may simply not be possible.

### **Approach**

In the face of these challenges, we propose a "control group" approach in which transportation GHG emissions per resident under BAU (based on monitoring the "control group" – a matched sample from a "comparison site") are compared with GHG emissions per TED resident (monitored in the project area).

Control groups are common in experimental and quasi-experimental research designs, when the purpose is to evaluate the treatment effects of an intervention on a population of interest. In theory, a true experimental design offers the most rigorous approach, via “randomization,” randomly placing individuals into “treatment” (TED) and non-“treatment” (non-TED) settings. Due to the impracticality of randomized experiments in our context, we propose a quasi-experimental design. Quasi-experimental designs, while more practical, introduce the “self-selection” problem (discussed above) and the subsequent risk of falsely inferring causality: in this case, attributing GHG reductions to TED when, in fact, the GHG differences come from unobserved characteristics.



**FIGURE 3 Methodology Flow Chart for Nanchang TOD Emission Reduction Evaluation**

A number of different approaches for strengthening causal inference in quasi-experimental designs exist (27). One standard technique involves matched sampling, which uses observed variables to adjust for differences in outcomes that are unrelated to the treatment (intervention) and that give rise to selection bias. Propensity-score matching (PSM) (e.g., 28) is particularly popular in evaluating social programs. Essentially, PSM enables a statistical assessment of the project and control group parameters

which, in our case, works to eliminate the effect of emissions differences arising from factors external to the project and/or random variations. A clear relation between the project activity and the measured emission reductions can thus be drawn.

Figure 3 provides an overview of the proposed methodology's main steps.

### Step 1: Selection of Comparison Site

This step entails the selection of “comparison sites” of similar size, land use characteristics and infrastructure conditions within the same metropolitan area. This intends to control for possible scale effect and other potentially confounding factors such as climate, density and public transit conditions. Nonetheless, this step faces criticisms due to potential arbitrariness. We suggest a maximum difference of 50% for size and 15% for density: too large a difference introduces geographically confounding variables and biases; too small a difference would make the methodology infeasible in most cases. For the South Chaoyang TOD project, we propose the “Honggutan” New District as the comparison site (Figure 4). Honggutan is:

- within Nanchang city;
- on the west side of the Gan Jiang river and relatively isolated from the project site, thereby reducing potential cross influences between the two sites and subsequent monitoring complications;
- a fairly recent development, begun in 2004, representing prevailing land development patterns in the city;
- comparable in expected size, with 100,000 residents in 2006 and 150,000 expected at completion, within 50% difference of Chaoyang TOD's planned population of 200,000;
- similar land use mix (Honggutan is also 50% residential use, but with more office while Chaoyang has more commercial usage).
- Similar transportation characteristics, using the criteria of road density and density of public transport stops.

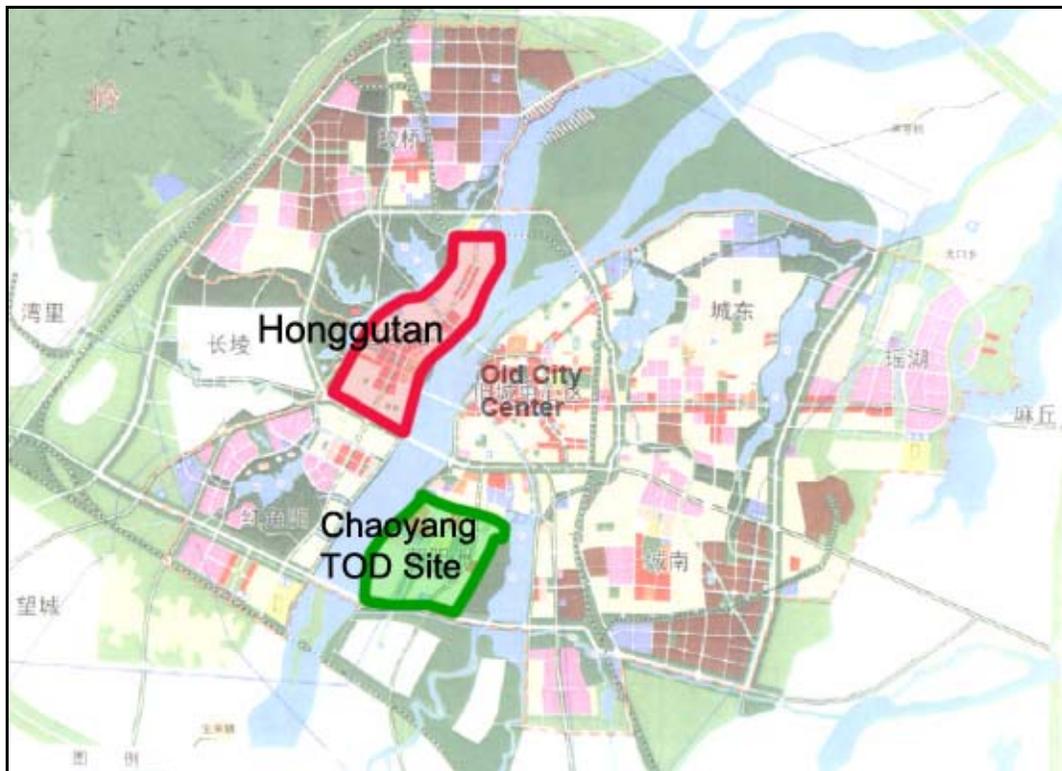


FIGURE 4 The location of the “Comparison Site”—Honggutan New District

The comparison site approach also presents a time-frame challenge, since the project has a proposed 30-year lifetime. The comparison site initially chosen may no longer be “comparable” after a few years. In contexts of rapid changes – where large scale infrastructure projects (highways, subways, etc.) are the norm – the “comparison site” should be selected at each monitoring year, and, if necessary, combined sites can be used to meet the size criteria. We propose bi-annual monitoring of baseline and project emission parameters to reduce costs, under the assumption that parameter changes do not occur that quickly and dramatically. In other words, monitoring would take place in years 1, 3, 5, and 7 for the first CDM crediting period, with year 1-monitored parameters used for year 2, year 3-monitored parameters used for year 4, etc. Monitoring continues until calculated emission reductions per person/resident stabilize within a 10% variation. If, for a minimum 3 consecutive monitoring years (i.e. at least 5 years’ time), monitored emission reductions per person remain within a range of  $\pm 10\%$  then the emission reduction factor per person/resident can be assumed constant and monitoring can be reduced to determining the number of persons/residents. Emission reductions are then calculated based on the number of persons/residents and the respective emission reduction factor. Monitoring would be resumed again with implementation of additional, or elimination of, TED measures. Otherwise TED measures can be assumed to have had their effect, with no additional TED-influenced changes expected. This enables a substantial potential reduction in monitoring costs.

## **Step 2: Construct “Control Group” through Propensity-Score Matching (PSM)**

After controlling for geographically confounding variables by selecting “comparison sites,” we propose the use of PSM to control for individually confounding variables. This step consists of constructing the “control group” sample from the sampling frame of comparison units. The use of PSM to control for selection bias rests on a key assumption that selection (whether or not a resident chooses to live in the project area) is due to observable variables (e.g. income, age, employment status, attitudes, etc.) which can be collected and monitored through a household survey.

These observed variables are called covariates, defined as any variable not affected by the treatment (i.e., living in the TED area). Any demographic or socioeconomic attribute of a resident represents a covariate, but post-treatment outcomes (travel behavior) do not. The propensity score is the probability of being treated, conditional on the covariate – that is, the conditional probability of residing in the TED, or not. A binary logit model can be used to estimate this probability. We recommend Dehijia and Wahba’s (29) procedure for estimating the propensity score: start with a parsimonious logit model; sort sample respondents by the estimated propensity scores; stratify all observations to eliminate statistically significant differences in estimated scores between intra-stratum treated and comparison units (for all covariates, check that the differences in means across treated and comparison units within each stratum are not significantly different from zero); if covariates are not balanced for some stratum, divide the stratum into finer strata and re-evaluate; if a covariate is not balanced for many strata, modify the model by adding interaction terms and/or higher-order terms of the covariate and re-evaluate.

Even with this procedural guideline, robust propensity score estimation is a challenge. The procedure involves judgmental decisions in model specification, setting the cutoff points for strata, selecting important covariates to balance (in practice not all covariates can be balanced), etc. Modeling and survey design experience will clearly be needed. The travel behavior literature and practice offers important precedents for developing sample survey questions for matching covariates, including those affecting residential location choice and travel behavior. However, debates continue on how survey questions might best capture attitudinal variables.

Furthermore, different matching metrics and matching methods might produce different results. Several approaches seem promising, such as one-to-one nearest neighbor matching or caliper matching. Matching with replacement should be used to reduce bias and sensitivity analysis should be conducted to reveal differences resulting from using different matching metrics or methods. Ultimately, implementation of the approach will require statistics experience to effectively balance the need for bias

reduction and efficiency achievement. This additional modeling and analysis will increase project costs and risks.

### Step 3: Calculate Transportation Energy Use and GHG Emissions

This step takes the relevant travel behavior components – trip rates and distances, mode shares, and occupancy levels (see Figure 1), derived primarily from the household survey (supplemented by other sources to calculate vehicle occupancies) – to estimate the ultimate outcome of interest: differences in GHG emissions. Here key questions relate to: the number of survey days needed to generate reliable activity estimates; and the validity and reliability of the travel survey instrument – which must be capable of generating relatively precise estimates of trip-making behavior, including travel distances. New technologies, such as GPS-enabled devices, could play an important role. The subsequent parameters estimated can be used to calculate the project’s total annual emissions reductions in year  $y$ ,  $ER_y$ :

$$ER_y = BE_y - PE_y \quad (1)$$

where:

$$BE_y = \sum_i \frac{R_{BL,i,y} \times TR_{BL,i,y} \times TD_{BL,i,y} \times EF_{BL,PKM,i,y}}{10^6} \quad (2)$$

$$PE_y = \sum_i \frac{R_{PJ,i,y} \times TR_{PJ,i,y} \times TD_{PJ,i,y} \times EF_{PJ,PKM,i,y}}{10^6} \quad (3)$$

$BE_y$	Baseline emissions in year “y” (tCO <sub>2</sub> )
$R_{BL,i,y}$	Total residents using vehicle category “i” in year “y” in the baseline scenario
$TR_{BL,i,y}$	Baseline average number of trips of made by residents by vehicle category “i” in year “y”
$TD_{BL,i,y}$	Baseline average trip distance (kilometer) by vehicle category “i” in year “y”
$EF_{BL,PKM,i,y}$	Baseline emission factor per passenger-kilometer (grCO <sub>2</sub> /PKM) for vehicle category “i” in year “y”
$PE_y$	Project emissions (tCO <sub>2</sub> ) in year “y”
$R_{PJ,i,y}$	Total residents using vehicle category “i” in year “y” in the project site
$TR_{PJ,i,y}$	Average number of trips of made by residents in the project site by vehicle category “i” in year “y”
$TD_{PJ,i,y}$	Average trip length (kilometer) by vehicle category “i” in year “y” in the project site
$EF_{PJ,PKM,i,y}$	Project emission factor per passenger-kilometre (grCO <sub>2</sub> /PKM) by vehicle category “i” in year “y”

### Possible Leakages

Beyond the aforementioned leakage challenge (i.e. the “elephant in the room”), TED faces a number of additional leakage-related effects (positive and negative):

- Potential movers – if the TED causes people to live outside the project boundary (i.e., those who would live in the project area without the TED), this could produce additional emissions (e.g., a car user who dislikes TED and therefore moves out and travels further); monitoring this type of activity would require additional data collection and increase monitoring costs.
- Constant emissions factors – the methodology assumes the same emission factors per kilometer for the project and baseline, but vehicle speeds may vary across the sites; monitoring for these differences would be complex, costly, possibly infeasible (comparison sites will always have different characteristics such as road size, traffic conditions), and impossible under the proposed control group approach.

- Freight/commercial transport – the methodology assumes no difference in emissions from non-passenger transportation between TED and non-TED.
- Constant non-transportation emissions – the methodology assumes no difference in upstream emissions (e.g., from site development/redevelopment, construction) between TED and non-TED and, furthermore, ignores any possible differences in non-transportation energy consumption between the two.
- Spillovers – neighboring areas may eventually copy TED characteristics and produce emissions effects; furthermore, those leaving the TED may bring with them new, more “carbon-efficient” transport behaviors which fall beyond the project boundary.

### **Financial Viability**

Methodological challenges may affect the financial viability of the proposed project. CDM project costs can be divided into emission reduction costs and transaction costs. Emission reduction costs for a TED project include the potential loss of land value by changing the land use categories around public transit stations, a negative cost premium from not “up-scale” project perceptions, as well as any incremental cost differences arising from TED relative to a non-TED alternative. Transaction costs include upfront project initiation, documentation, validation, registration, regular verification, issuance fees, adaptation fund, local taxes, and monitoring costs. As the methodology entails continuous household surveys to calculate emissions reductions, monitoring costs are relatively high. Revenues come from the total emission reductions and the CER price. Under fairly aggressive mode shift assumptions (2 to 5 percent increase of bus share and 4 to 5 percent increase of NMT share from motorcycle, private car, and taxi shares) and occupancy rate increase (10% increase of bus occupancy rate) in the Nanchang TOD case, the project generates 60,000 tCO<sub>2e</sub> reductions over the first 7-year crediting period; at 2010 CER prices, this translates into roughly US\$2 million.

However, a TED-type project faces additional risks which could influence the total financial flows generated from CERs, including: a potentially higher-than-typical difference between actual and projected CERs; and, a higher risk of non-approval of the monitoring report (due to complexity) and subsequent non-issuance of CERs. Both of these factors lead to higher uncertainty regarding CER issuance levels which reduces the potential price the proponent could fetch in pre-established contracts. In China this is not too important since projects in the country need to pay a pre-established floor price; so the price paid for a TED project will be roughly the same as for other projects.

### **Co-benefits**

As mentioned above, in theory the CDM should act as a “dual purpose” instrument, achieving GHG emissions reductions and delivering so-called “co-benefits.” In practice, however, “co-benefits” have received little weight in project evaluation by the CDM Executive Board. The majority of currently registered CDM projects have been non-energy projects (e.g., HFC capture), which, while bringing good climate value for money, likely have minimum local development dividends (14). Despite this apparent lack of importance in current CDM activities, the potential co-benefits of TED in the Chinese context need to be highlighted. These might include: improved energy security (reduced petroleum dependence), reduced local air and noise pollution, improved accessibility, increased productivity (e.g., 24), farmland and open space preservation, enhanced social equity and traffic safety, knowledge transfer (including data collection), etc. Not all of these “co-benefits” will necessarily arise from TED implementation and some trade-offs may exist among them. Nonetheless, a thorough co-benefits analysis would be important for understanding the scope of local TED benefits, improving the relevant methodologies for future project evaluations, and for demonstrating co-benefits analysis techniques for ongoing CDM and climate change mitigation dialogues.

### **CONCLUSION**

In theory, Chinese cities have the opportunity to reap great potential long-term benefits – including emissions reductions, energy security, urban productivity, etc. – from implementing TED. Can the main

market mechanism for developing country GHG reduction – the CDM – be effectively utilized to help build an energy-efficient and less emissions-intensive urban transportation future in China via TED? To help answer this question we propose a methodology to quantify the emission reduction benefits of TED projects, demonstrating its potential application in the case of the Nanchang TOD project. The methodology reveals a number of challenges to utilizing CDM for TED. The “control group” approach faces difficulties in arbitrary geographical control (by selecting “comparison sites”), propensity-score estimation and matching, and leakage calculations. These methodological difficulties also lead to financial viability challenges because of high monitoring costs and project risks. Ultimately, it remains to be seen whether the CDM Executive Board will accept a behavioral change-oriented methodology, which requires statistical control approaches as perhaps the only effective means of verifying emissions reductions.

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