

**FRAMEWORK FOR INTEGRATED PLANNING OF BUS AND
PARATRANSIT SERVICES IN INDIAN CITIES**

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**FRAMEWORK FOR INTEGRATED PLANNING OF BUS AND
PARATRANSIT SERVICES IN INDIAN CITIES**

by

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Certificate

This is to certify that the thesis entitled, '**Framework for integrated planning of bus and paratransit services in Indian cities**' being submitted by **Mr. S B Ravi Gadepalli** to the **Indian Institute of Technology Delhi**, is a record of the bona-fide research work carried out by him under our supervision. The thesis, in our opinion, is worthy of consideration for the award of the degree of **Doctor of Philosophy** in accordance with the regulations of the Institute. The results embodied in the thesis have not been submitted to any other University or Institute for the award of any degree or diploma.

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Abstract

Public transport services in India and many other developing countries are provided by a combination of formal-Government led public transport systems and informal paratransit or Intermediate Public Transport (IPT) systems, which offer shuttle services along high demand corridors with passengers boarding and alighting at multiple points. Despite limited Government support, paratransit systems continue to thrive in many cities serving a crucial shared mobility need of users, without which cities would have more private vehicle usage. Due to their informal nature and the perceived competition to formal public transport systems, they have traditionally been either excluded from the public transport planning processes or designed as a feeder service to the formal transit system. The current thesis recognises paratransit's role in serving end to end travel demand needs, particularly in developing economies with limited public transport supply and not just being a feeder to the formal public transport system. Hence, we develop an integrated planning framework that enables formal and informal public transport systems to operate as complementary systems towards meeting the mobility needs of the city.

We proved an integrated planning framework based on comprehensive understanding of the demand and supply characteristics of both formal and informal systems which currently operate independently to realign services and complement each other. The tactical planning stage of public transport planning i.e. frequency setting was identified as the ideal stage of planning for integration of the two types of services. This will ensure continuity of their existing route networks and at the same time allow for paratransit services' flexibility to switch operations between routes. Visakhapatnam, a representative medium sized Indian city with a significant presence of formal public transport in the form of city bus services and paratransit services provided by three-wheeler

auto-rickshaws with a seating capacity of three to six passengers, was selected as the case city to demonstrate the methodology.

A household survey based data collection and analysis methodology was adopted to analyse the socio-economic and travel demand characteristics of city bus and paratransit users. The variables impacting users' choice between these two systems were derived through binary logistic regression. The high frequency and low occupancy paratransit systems were more popular among shorter trips, while longer trips preferred the fixed table bus systems.

The operational characteristics of bus and paratransit systems were derived through a combination of primary surveys with paratransit operators and secondary data on the city bus operations. Data regarding their network of operation, services offered, passenger demand and revenue generated were collected for analysis. Buses perform a service function in the city by operating throughout the day and on a wider network, while paratransit operates with a profit motive only on high demand corridors and during peak hours. A Data Envelopment Analysis (DEA) based methodology was adopted to compare the performance efficiency of the two systems using a set of input and output indicators that define the performance of the two systems. Paratransit operations were identified to be more efficient compared to buses, due to their demand responsive operations. The lower efficiency of buses was also due to their service obligation to the city to provide affordable services throughout the day, even in areas with low demand.

A bi-level transit assignment and frequency optimisation framework is developed to integrate formal bus and paratransit services. The lower-level of the model solves for the multi-modal transit assignment problem while the upper level solves for the integrated frequency optimisation problem. The transit assignment problem was solved from the users perspective i.e. to minimise their travel time through the user-equilibrium method. The frequency optimisation

problem was solved using an integer programming formulation with the objective of minimising operational cost of bus and paratransit systems while meeting constraints like the travel demand on any link

The outputs from the optimisation exercise were used to quantify the impact of the public transport system at various levels i.e. users total travel time spent in the system, operators cost of providing the services and the overall impact on the society by estimating its road space requirement and emissions. Alternative user demand and transit supply scenarios were tested to assess their impacts on the society. The results show significant operational cost benefits of an integrated transit assignment and frequency planning approach where paratransit provides demand responsive services for short distance trips while formal public transport provides fixed schedule services on with broader network coverage.

The analysis established the complimentary role played by bus and paratransit systems in meeting users travel demands. Therefore, it is recommended that cities harness both the systems towards meeting increasing travel needs of developing economies. Formal transit will continue to be the core of the public transport system, providing fixed route services, while paratransit can augment its capacity on high demand corridors and during peak hours. The planning and frequency optimisation framework developed in this thesis can help cities in identifying the modal-mix of fixed route public transport and on-demand services.

सार

भारत और कई अन्य विकासशील देशों में सार्वजनिक परिवहन सेवाएं औपचारिक सरकारी नेतृत्व वाली सार्वजनिक परिवहन प्रणालियों और अनौपचारिक पैराट्रांसिट या इंटरमीडिएट पब्लिक ट्रांसपोर्ट .आईपीटी. प्रणालियों के संयोजन द्वारा प्रदान की जाती हैं, जो यात्रियों को बोर्डिंग और अलाइटिंग के साथ उच्च मांग वाले गलियारों में शटल सेवा प्रदान करती हैं। अंका सीमित सरकारी समर्थन के बावजूद, पैराट्रांसिट सिस्टम उपयोगकर्ताओं की एक महत्वपूर्ण साझा गतिशीलता की सेवा करने वाले कई शहरों में पनपना जारी रखता है, जिसके बिना शहरों में अधिक निजी वाहन का उपयोग होता। उनकी अनौपचारिक प्रकृति और औपचारिक सार्वजनिक परिवहन प्रणालियों की कथित प्रतिस्पर्धा के कारण, उन्हें पारंपरिक रूप से सार्वजनिक परिवहन नियोजन प्रक्रियाओं से बाहर रखा गया है या औपचारिक परिवहन प्रणाली के लिए फीडर सेवा के रूप में डिज़ाइन किया गया है। वर्तमान थीसिस यात्रा की अंतिम जरूरतों को पूरा करने में पैराट्रांसिट की भूमिका को पहचानती है, विशेष रूप से सीमित सार्वजनिक परिवहन आपूर्ति के साथ विकासशील अर्थव्यवस्थाओं में और न केवल औपचारिक सार्वजनिक परिवहन प्रणाली के लिए एक फीडर होने के रूप में। इसलिए, हम एक एकीकृत योजना ढांचा विकसित करते हैं जो औपचारिक और अनौपचारिक सार्वजनिक परिवहन प्रणालियों को शहर की गतिशीलता आवश्यकताओं को पूरा करने के लिए पूरक प्रणालियों के रूप में संचालित करने में सक्षम बनाता है।

हमने औपचारिक और अनौपचारिक दोनों प्रणालियों की मांग और आपूर्ति विशेषताओं की व्यापक समझ के आधार पर एक एकीकृत नियोजन ढांचे को साबित किया जो वर्तमान में वास्तविक सेवाओं के लिए स्वतंत्र रूप से काम करते हैं और एक दूसरे के पूरक हैं। सार्वजनिक परिवहन योजना की आवृत्ति नियोजन चरण अर्थात् आवृत्ति सेटिंग को दो प्रकार की सेवाओं के एकीकरण के लिए नियोजन के आदर्श चरण के रूप में पहचाना गया

था। यह उनके मौजूदा मार्ग नेटवर्क की निरंतरता सुनिश्चित करेगा और साथ ही मार्गों के बीच संचालन को बदलने के लिए पैराट्रांसिट सेवाओं के लचीलेपन की अनुमति देगा। विशाखापत्तनम, एक प्रतिनिधि मध्यम आकार का भारतीय शहर, जिसमें तीन से छह यात्रियों के बैठने की क्षमता के साथ श्रीःव्हीलर ऑटोःरिक्शा द्वारा प्रदान की जाने वाली सिटी बस सेवाओं और पैराट्रांसिट सेवाओं के रूप में औपचारिक सार्वजनिक परिवहन की महत्वपूर्ण उपस्थिति थी, कार्यप्रणाली को प्रदर्शित करने के लिए इसे केस सिटी के रूप में चुना गया था।

सिटी बस और पैराट्रांसिट उपयोगकर्ताओं की सामाजिकःआर्थिक और यात्रा मांग विशेषताओं का विश्लेषण करने के लिए एक घरेलू सर्वेक्षण आधारित डेटा संग्रह और विश्लेषण पद्धति को अपनाया गया था। इन दो प्रणालियों के बीच उपयोगकर्ताओं की पसंद को प्रभावित करने वाले चर बाइनरी लॉजिस्टिक रीग्रेशन के माध्यम से प्राप्त किए गए थे। उच्च आवृत्ति और कम ऑक्यूपेंसी पैराट्रांसिट सिस्टम छोटी यात्राओं के बीच अधिक लोकप्रिय थे, जबकि लंबी यात्राएं निश्चित टेबल बस सिस्टम को पसंद करती थीं।

बस और पैराट्रांसिट सिस्टम की परिचालन विशेषताओं को सिटी बस संचालन पर पैराट्रांसिट ऑपरेटरों और माध्यमिक डेटा के साथ प्राथमिक सर्वेक्षण के संयोजन के माध्यम से प्राप्त किया गया था। उनके संचालन के नेटवर्क, सेवाओं की पेशकश, यात्री की मांग और राजस्व के बारे में डेटा विश्लेषण के लिए एकत्र किए गए थे। पूरे दिन और व्यापक नेटवर्क पर बसें शहर में एक सेवा कार्य करती हैं, जबकि पैराट्रांसिट केवल उच्च मांग वाले गलियारों और पीक ऑवर्स के दौरान लाभ के उद्देश्य से संचालित होता है। दो प्रणालियों के प्रदर्शन को परिभाषित करने वाले इनपुट और आउटपुट संकेतकों के एक सेट का उपयोग करके दो प्रणालियों के प्रदर्शन दक्षता की तुलना करने के लिए एक डेटा एनवेलमेंट एनालिसिस .डीईए. आधारित कार्यप्रणाली को अपनाया गया था। पैराट्रांसिट संचालन की पहचान बसों की तुलना में अधिक कुशल होने के कारण की गई थी, क्योंकि उनकी मांग उत्तरदायी परिचालन के कारण थी। कम मांग वाले क्षेत्रों में भी बसों की कम दक्षता शहर में दिन भर में सस्ती सेवाएं प्रदान करने के लिए उनके सेवा दायित्व के कारण थी।

औपचारिक बस और पैराट्रांसिट सेवाओं को एकीकृत करने के लिए एक द्विःस्तरीय पारगमन असाइनमेंट और आवृत्ति अनुकूलन रूपरेखा विकसित की जाती है। मॉडल का निचलाःस्तर बहुःमोडल पारगमन असाइनमेंट

समस्या के लिए हल करता है जबकि ऊपरी स्तर एकीकृत आवृत्ति अनुकूलन समस्या के लिए हल करता है। पारगमन असाइनमेंट की समस्या को उपयोगकर्ताओं के दृष्टिकोण से हल किया गया था, अर्थात् उपयोगकर्तासंतुलन विधि के माध्यम से अपनी यात्रा के समय को कम करने के लिए। फ्रीक्वेंसी ऑप्टिमाइज़ेशन समस्या को किसी भी लिंक पर यात्रा की मांग की तरह बाधाओं को पूरा करते हुए बस और पैराट्रांसिट सिस्टम की परिचालन लागत को कम करने के उद्देश्य से पूर्णांक प्रोग्रामिंग फॉर्मूला का उपयोग करके हल किया गया था।

ऑप्टिमाइज़ेशन एक्सरसाइज से आउटपुट का उपयोग विभिन्न स्तरों पर सार्वजनिक परिवहन प्रणाली के प्रभाव को निर्धारित करने के लिए किया गया था अर्थात् उपयोगकर्ता सिस्टम में बिताए गए कुल यात्रा समय, ऑपरेटरों को सेवाएं प्रदान करने की लागत और इसके सड़क स्थान की आवश्यकता का आकलन करके समाज पर समग्र प्रभाव और उत्सर्जन। वैकल्पिक उपयोगकर्ता की मांग और पारगमन आपूर्ति परिदृश्यों का समाज पर उनके प्रभावों का आकलन करने के लिए परीक्षण किया गया था। परिणाम एक एकीकृत पारगमन असाइनमेंट और आवृत्ति नियोजन दृष्टिकोण के महत्वपूर्ण परिचालन लागत लाभ दिखाते हैं, जहां पैराट्रांसिट कम दूरी की यात्राओं के लिए उत्तरदायी सेवाएं प्रदान करता है, जबकि औपचारिक सार्वजनिक परिवहन व्यापक नेटवर्क कवरेज के साथ निर्धारित कार्यक्रम सेवाएं प्रदान करता है।

विश्लेषण ने उपयोगकर्ताओं की यात्रा की मांगों को पूरा करने में बस और पैराट्रांसिट सिस्टम द्वारा निभाई गई मानार्थ भूमिका की स्थापना की। इसलिए, यह सिफारिश की जाती है कि शहरों में विकासशील अर्थव्यवस्थाओं की बढ़ती यात्रा आवश्यकताओं को पूरा करने की दिशा में दोनों प्रणालियों का उपयोग किया जाए। औपचारिक पारगमन सार्वजनिक परिवहन प्रणाली का मुख्य हिस्सा बना रहेगा, जो निश्चित मार्ग सेवाएं प्रदान करता है, जबकि पैराट्रांसिट उच्च मांग गलियारों और पीक घंटों के दौरान अपनी क्षमता को बढ़ा सकता है। इस थीसिस में विकसित नियोजन और आवृत्ति अनुकूलन ढांचा निश्चित मार्ग सार्वजनिक परिवहन और ऑनडिमांड सेवाओं के मॉडलमिश्रण की पहचान करने में शहरों की मदद कर सकता है।

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