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Integrated Transportation Strategy to Address Industrial Development Externalities

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***Abstract*—As industries move to developing countries, many of these countries struggle with negative externalities. The negative externalities of industrial park development, such as severe traffic congestion and its derivative problems, such as increased air pollution and road safety risks, require serious attention. Addressing these externalities requires an integrated approach that combines several strategies. Current literature shows a fragmented approach to addressing the transportation problem with a limited understanding of how integrating various strategies simultaneously create a cumulative impact. In addition, the type of strategies and practical implementation of the integrated transportation strategy in the developing country remains unexplored. This research aims to develop an integrated transport strategy by combining four prominent strategies, including supply management, demand management, land use planning, and institutional aspects, and test it empirically in a developing country case. We simulated several scenarios using quantitative comparative analysis to evaluate the effectiveness of the proposed combined strategies in solving traffic congestion in Morowali Industrial Park, Indonesia, the world's largest producer of materials for electric vehicle batteries, which is currently facing traffic congestion problems. Our finding demonstrates that an integrated transportation strategy that combines demand, supply, and land use management can solve traffic congestion more effectively than a partial strategy. The success of the integrated transportation strategy requires a clear division of responsibilities and stakeholders' collaboration. This result carries important policy implications for the combined scenario as an integrated strategy to overcome transportation problems.**

***Keywords*— Industrial Park; transportation externality; integrated transportation strategy.**

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I. INTRODUCTION

While developed countries are moving their industries abroad, many developing countries that are becoming new industrial locations are struggling with the negative externalities of this industrialization. This paper provides an example of how the industrialization process in developing countries creates negative externalities in the transportation sector. Moreover, developing countries face increasing urbanization that exceeds their capacity to provide adequate services to their citizen [1]. This excessive urbanization, in turn, triggers a higher concentration of industries [2]. In the transport sector, this looping process creates an imbalance of transport demand and supply that can trigger traffic congestion.

Current literature shows various approaches to implementing "integrated strategies" to solve the aforementioned transport problem. For example, this integration can refer to transport and land use planning [3]. In other cases, this integration can refer to integrating transport supply, demand, and land use management [4]. In another case, this integration extends to institutional aspects since transportation problems in emerging economies sometimes also relate to non-technical aspects, such as a lack of institutional setup [5], a complex institutional environment [6], and governance problems [7]. Even though these various strategies have paved the way to conceptualizing an integrated transport strategy, there is still a limited understanding of how integrating all these strategies simultaneously creates a more enormous cumulative impact, especially in the context of developing countries. In response to this, this research aims to develop an innovative integrated transportation strategy that combines four criteria (transport supply, transport demand, land use management, and institutional aspect) to address traffic congestion caused by industrial park development in developing countries by selecting Morowali Industrial Park in Indonesia as a case study.

In the Indonesian context, the industrial sector is one of the prime sectors that contributes significantly to the economic growth of the country [8], [9]. During the COVID-19 pandemic, the industrial sector was the most significant contributor to the Indonesian Gross Domestic Product (GDP), with a share of 17.89%, and created IDR 272.9 trillion in investment in 2020. According to the data of the Indonesian Ministry of Industry, the industrial sector's export value reached USD 131.13 billion in 2020, contributing 80.30% to national exports.

However, industrial development often creates negative externalities in the transportation sector, such as traffic congestion [10]. In many cases, developing a new industrial park changes the trip volume and the trip distribution of the surrounding area, demanding the need for transportation system adjustment. Such an occurrence arises due to the interwoven relationship between the transportation system with the activity system, in which these two components can influence each other [11], [12]. Moreover, rapid industrialization is putting pressure on transportation infrastructure. However, many industrial park development plans fail to anticipate transportation changes in the surrounding area. This phenomenon reflects developing countries' common planning failure, where market forces often drive planning rather than a visionary and comprehensive plan [13].

This paper discusses the implications of industrial park development on the transportation sector and how to cope with traffic congestion as the negative externalities of industrialization. We selected Morowali Industrial Park as a case study. This ferronickel mining and smelter cluster emerged as one of the most significant investments in Indonesia [14]. Morowali Industrial Park represents central and local government plans to boost economic development, especially with the rapid development of electric vehicles trend where nickel is the main raw material for the batteries. The National Industrial Development Plan 2015-2035 establishes Morowali as part of the Industrial Growth Center Area that is projected to play a vital role as the national economy's prime mover. The Morowali Regency Spatial Plan 2019-2039 designates Morowali Industrial Park as a large-scale industrial area. However, these national and local government plans show a lack of clear guidance on coping with the resulting transportation externalities.

This paper proposes an integrated solution that combine several scenarios on how to respond to the traffic problems, that not only combining technical strategies, such as, supply-demand management, and land use planning, but also institutional integration with argument that the success of the approach very much depends on good coordination and strong commitment of all stakeholders. Transport scenario is considered useful to examine alternative future narratives when business-as-usual is not appropriate [15], [16].

To empirically test this integrated transportation strategy, we apply a scenario simulation approach with a quantitative comparative analysis technique by measuring the volume capacity ratio of this combination of technical and institutional aspects. The data used in the simulation comes from the traffic counting data gained at the three-road section that became access points of the Morowali Industrial Park. To take an institutional aspect into account, we triangulated this technical simulation in a series of seminars with stakeholders representing the central and local government, the Morowali Industrial Park manager and developer, and a transportation expert.

Following this introduction, section two elaborates on the concept of integrated transportation strategy and the methodology applied in this research. Section three discusses the simulation result of this concept in the case of Morowali Industrial Park. Lastly, section four concludes.

II. Materials and Methods

A. *Integrated Transportation Strategy*

Industrial areas are a type of land use with a high potential for trip attraction [17], [18]. Labor-intensive industries attract huge daily working trip volumes during morning and afternoon peak hours. In many developing countries, industrial park development is often driven by immediate market demand rather than being a product of visionary and comprehensive planning [13]. Many cities are facing transportation problems as their road development plans fail to anticipate future traffic levels. Such planning failures often result in acute traffic congestion, which demand several approaches to be combined.

Integrated transport strategies are concerned with accommodating land use management into transportation plans. The changes in accessibility affect land use, location, and mobility behavior [3]. To date, current researches define integrated transport strategies differently, such as the integration of the supply, demand, and land use management [4], or as an integrated transport-land use strategy [3]. Instead of considering supply-demand and land use management, we considered taking participatory, social, and governance aspects into account. A participatory approach that engages the broadest range of participants is essential and provides legitimacy to transportation-land use planning [19]. In addition, the desired social outcomes should be agreed upon and be a common agenda of all stakeholders at all level [20]. It is important to note that land use planning is a complex process and is more effective if it is part of a cohesive, integrated strategy for long-term development [21]. Instead of adopting these three components (supply, demand, and land use management), we proposed a fourth element, the institutional integration component, as this is a critical factor for the success of the overall strategy [22], [23].

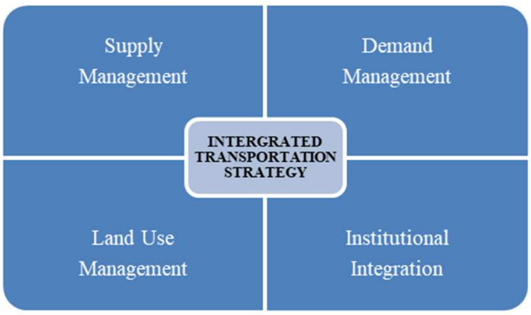

Fig. 1 Integrated Transportation Strategy

1) Supply Management: The provision of infrastructure, such as road widening, would increase road capacity, yet stimulate further traffic growth [11], [24]. Increasing road capacity is not always become an efficient solution to manage congestion [25]. Even though widening the existing road could be an efficient alternative to reduce congestion in the short run, it may not reduce travel time in the long run [26]. In addition, road widening projects might face high social costs, such as social conflict resulting from building relocations affected by road widening projects.

2) Demand management: Many countries have implemented demand management strategies such as time-shifting, route-shifting, and mode-shifting. Several previous studies have indicated that time and route-shifting of activities could mitigate congestion [27], [28]. Time-shifting through promotion-based systems or incentives can effectively spread workers' trips from peak periods to off-peak periods [29]. Meanwhile, a mode-shifting strategy, through prioritizing policy that focuses on improving public transport service quality, can effectively reduce private vehicle ownership and use [30].

3) Land use management: Many studies imply an interaction between land use and transportation [4], [31]. The traffic volume depends on the land use characteristics of the area [32]. Therefore, land use planning is the instrument that influences future traffic volume and distribution patterns. Yet, effective land use planning requires a proper participatory process, adjustment of regulations, and robust implementation control [15], [19], [33], [34].

4) Institutional integration: This factor is also crucial to an integrated transportation strategy [22], [23]. It relates to inter-party collaboration in transportation plans and implementation. A clear agenda with a clear division of responsibilities among the executing agencies, i.e. central government, local governments, and industries is essential to reduce misconduct in planning and implementation. Identifying key roles and actions taken by different actors among diverse institution is a meaningful and helpful approach for solving complex transport problems [35].

B. Methodology

This research simulated and evaluated the effectiveness of several scenarios to overcome the transportation problems in a typical emerging industrial area, by taking the Morowali Industrial Park as a case study. These scenarios were based on the integrated transport strategies as we conceptualized in Section A, comprising supply management, demand management, land use planning, and institutional integration. The study evaluated the effectiveness of each scenario by comparing the current volume-to-capacity ratio (VCR) with the predicted VCR after implementing the scenarios. We gradually combined scenarios to see the effectiveness of the integrated transport strategies in solving traffic congestion in the case study area.

We observed the initial/current traffic volume through a traffic count in the two peak hours period, morning peak hours (06.00 to 08.00 AM) and afternoon peak hours (04.00 to 06.00 PM), to represent the traffic characteristics of the weekdays. In addition, we also observed traffic volume on weekends to gain a comprehensive traffic characteristic of the case study area. The survey was conducted for three days, on 27–29 March 2021. Weekday characteristics were represented by traffic counting carried out on Monday, while traffic counting on Saturday and Sunday represented weekend characteristics. Traffic was counted at four access points to and from Morowali Industrial Estate, at entrance roads leading to parking area Sections 1, 2, 3, and 4. Figure 3 shows the location of those four parking sections. We classified the vehicle into three types: (1) light vehicles, including light passenger vehicles, minibuses, and pick-up cars; (2) heavy vehicles comprising trucks; and (3) two-wheeled motorcycles. This variation in times, days, and vehicle type allows for comparing traffic saturation levels between times and days. This data was essential information for traffic distribution scenarios in each strategy simulation. Future traffic volume was projected to grow three times following the industrial park's plan to triple the number of employees in Morowali Industrial Park (up to 100.000 employees) in the coming years. Other data included road network and geometry, working schedules, parking arrangements, and land use patterns.

We predicted the impact of the infrastructure *supply management scenario* by assuming the local government can optimize the road width in the future, so we can compare the initial VCR with the future VCR after the road improvement. We used the Indonesian Highway Capacity Manual (IHCM) to generate the VCR. The VCR is determined by dividing traffic volume by road capacity, as shown in equation (1). Meanwhile, road capacity is calculated through equation (2).

$$VCR = \frac{Volume\ (pcu\ per\ hour)}{Capacity\ (pcu\ per\ hour)} \tag{1}$$

$$C = C_0\ .FC_w.FC_{SP}.FC_{SF}.FC_{CS} \tag{2}$$

where:

- C Road Capacity (passenger car unit/ hour).
- C_0 Base Capacity (passenger car unit/ hour). The IHCM determines the base capacity of a two-way and two-lane undivided road as 2,900 passenger car unit/ hour.
- FC_W Road Adjustment Factor. The IHCM determines FCW = 0.56 for road with effective width of 5 meters, and FCW= 1.25 for road with effective width of 9 meters.
- FC_{SP} Directional Separator Adjustment Factor. The IHCM determines that FCSP is 1 if both road directions are divided equally by a ratio of 50% capacity.
- FC_{SF} Side Resistance and Roadside Factor. The IHCM determines the FCSF ranging from 0.73 to 0.94 if the roadside is less than 0.5 meters, and from 0.79 to 0.96 if the roadside is 1 meter. The value is adjusted to the five classifications of side resistance: very low (<100 disturbances per 200 meter), low (100 – 299 disturbances per 200 meter), medium (300 – 499 disturbances per 200 meter), high (500 – 899 disturbances per 200 meter), and very high (> 900 disturbances per 200 meter).
- FC_{CS} City Size Adjustment Factor. The IHCM determines that FCCS is 0.90 for a city with a population of 0.1 – 0.5 million.

We predicted the impact of the ***demand management scenario*** by simulating three strategies: time-shifting, route-shifting, and mode-shifting. First, we did a time-shifting simulation through rescheduling work starting and ending times. We selected time-shifting, since it is proven to effectively solve traffic congestion and distribute workers' trips from peak to off-peak hours [27], [29]. The traffic counting result demonstrates that the most severe peak hour is 07.00 – 08.00 AM. Therefore, the target of the new working time arrangement is to distribute the peak workers' trips from this period to other feasible times. However, the time-shifting scenario should follow the industrial working hours regulation, with no entry and exit to and from the industrial park allowed from 09.00 AM to 03.00 PM. Therefore, in this case, the time-shifting scenario distributed working trips evenly within 6 hours of peak time, i.e., 06.00-09.00 AM and 03.00-06.00 PM. We projected the VCR by adjusting two aspects: 1) We adjusted the traffic volume by referring to the industrial park plan to increase its size to 100.000 employees, and 2) We adjusted the capacity of the road in the future by optimizing its width by referring to the standard in Government Regulation No. 34/2006 regarding roads. To evaluate the scenario's effectiveness, we identified the projected VCR. By referring to the IHCM, it could be inferred that the closer the VCR to 1, the more enormous the potential for traffic jams.

Second, we did a route-shifting simulation based on reconfiguring parking areas. Previous research from Huang et al [36] applied a time-dependent equilibrium model for studying travelers' parking behavior. The study indicated that parking schemes such as increasing parking capacity, decreasing parking charges, and combining both would significantly influence people's travel and parking patterns. Motorcycle parking at Morowali is concentrated in one parking area (Section 3). Consequently, it has the most considerable portion of traffic volume. In the short term, this traffic accumulation can be split by shifting some traffic to a new parking area in the north. In the longer term, some other new parking areas must also be developed in the southern region to distribute higher traffic volume in the future, which is projected to triple. We projected this future VCR by assuming that parking areas would be implemented. Similar to the first scenario, to evaluate the scenario's effectiveness, we identified the projected VCR to see how significant this strategy was in pushing the VCR to less than 1.

Third, we did a mode-shifting simulation based on the scenario of shifting some motorcyclists to an employee's bus service. The more motorcyclists shifted to the bus, the better the VCR would be. This research took 30% mode-shifting from motorcycle to the employee's bus. To evaluate the scenario's effectiveness, we identified the projected VCR and checked its reduction.

We predicted the impact of ***the land use planning scenario*** by including a future new housing development scheme that can take place in the southern area of the industrial park. This scenario could distribute the trip origin volume currently concentrated in the north. This land use planning is considered effective, since the transport demand would be generated by how urban activities are organized [37]. A quantitative model to calculate the potential redistribution of trip origin volume to the south is based on the scenario of increased housing capacity. The simulation split the future number of trip origins into those living in the north and south. However, the target of this strategy could be achieved in the long term since it requires formal land use planning. In the simulation, we took this land use development, especially the residential areas in the southern part of this industrial park. We saw the influence on the traffic on the roads surrounding the area. Similar to the previous scenario, to evaluate the scenario's effectiveness, we observed the future value of its VCR and identified how close the value was to 1.

In the later stage, we applied a comparative analysis to compare the various combinations of aforementioned strategies to the current VCR to understand how significant integrated strategies can decrease the VCR. We illustrated these comparisons in Figure 16 of the results and discussion section. This scenario comprises two main scenarios to address current and future transportation problems. To address the current traffic jam problem, we compared these three scenarios that were predicted could reduce traffic jams:

a. Road widening resulted from the supply management strategy.
b. Time-shifting resulted from the demand management strategy.
c. The combination of time and route-shifting resulted from demand management strategies.

Meanwhile, to address future transportation problems, we applied combinations of the following strategies:

a. The combination of time-shifting and route-shifting resulted from demand management strategies.
b. The combination of time, route, and mode-shifting resulted from demand management strategies.
c. The combination of time, route, and mode-shifting with land use planning resulted from demand management and land use planning strategies.

To address the requirement of an ***institutional integration scenario*** for the success of strategy implementation, two seminars were conducted to communicate the transportation challenges, the potential benefits of the integrated strategy, and the sharing of responsibilities among stakeholders. The representatives from the central government, the local government, the expert, the Morowali Industrial Park management, and the communities were invited to the seminars.

To include this institutional aspect in the scenarios, since the asymmetric information regarding the benefits of the integrated transportation strategy often becomes a constraint for strong collaboration among stakeholders, we proposed a division of responsibility plan in addressing these various strategies as part of stakeholders' engagement. This division of responsibility comprised:

a. Engaging central government to optimize road capacity and actively involved in supply-demand management strategy, since the road passes the industrial park, is a national road.
b. Engaging the industrial park managers and developers to actively enhance time-shifting, route-shifting, mode-shifting, and land use planning by adjusting the working hours at the industrial park and providing a more sustainable shuttle to decrease motorcycle use.
c. Engaging local government to be deeply committed to supporting these time-shifting, route-shifting, mode-shifting strategies, and land use planning by integrating the industrial park development plan with the local spatial planning.
d. Engaging residents to actively supervise land use management by giving input to the local government to synchronize the industrial park with the residential areas surrounding it.

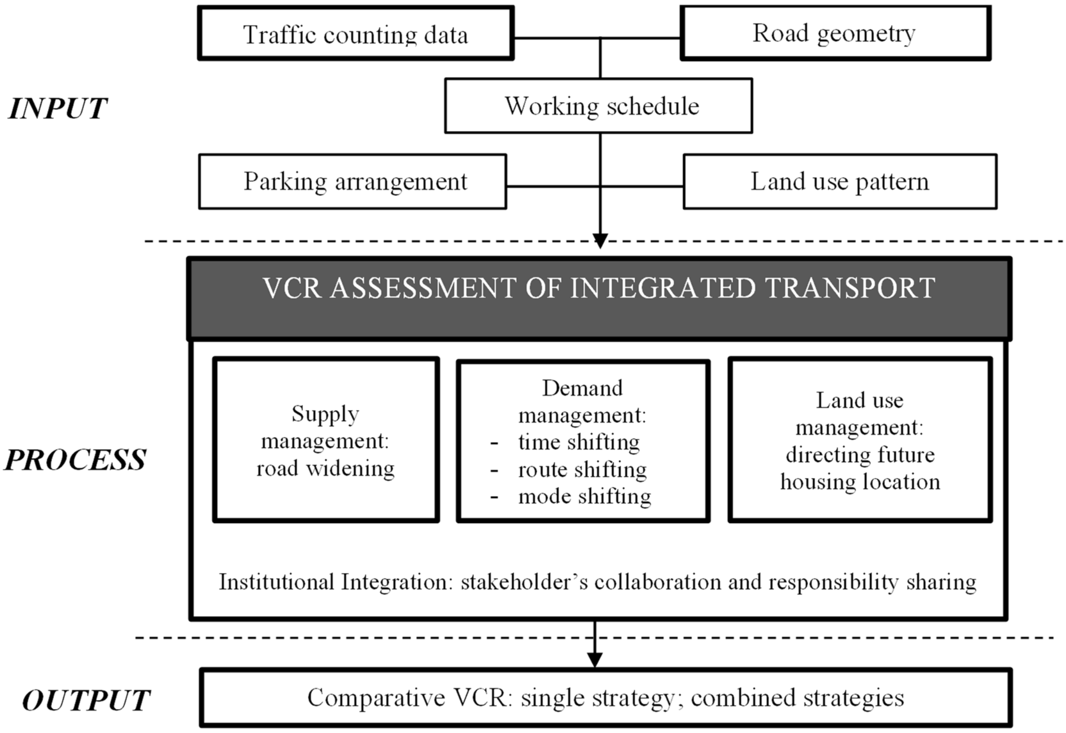

Fig. 2 Methodological Framework

III. Results and Discussion

A. Supply Management

Traffic congestion occurs when traffic volume exceeds the road capacity [33], [38]. Road widening is a promising solution from the supply management perspective as it would increase the road's capacity. In the case of Morowali Industrial Park, road widening is a relevant strategy given that the existing road width is still below national standards as stipulated in Law No. 38/2004 and Government Regulation No. 34/2006 concerning roads.

The Trans Sulawesi Road that passes Morowali Industrial Park is a national primary road that facilitates regional mobility. It is a hub for passenger and goods distribution, connecting Morowali Regency to the nearby airport and port. The road also plays a strategic role, providing access to the Kolonodale, a regional-level activity center, and Bungku Tengah Sub-district, Central Sulawesi Province's strategic local activity center.

According to Government Regulation 34/2006, Trans Sulawesi National Road is a primary collector road with a minimum width of 9 meters and designed for a minimum speed of 40 kph. Meanwhile, the road width in 2021 was 5 meters. With around 32,000 employees working in Morowali Industrial Park in 2021, the road's peak hour volume to capacity ratios (VCRs) were above 1, particularly at roads leading to parking area Sections 2 and 3 (See Figure 3 for details). Using the Indonesian Highway Capacity Manual (IHCM), we calculated the impact of road widening to 9 meters. Figure 4 shows that the increased road capacity would reduce the VCR at all roads to less than 1. At the peak time, between 06.00 AM and 08.00 AM, the highest VCR value was predicted to be only 0.86.

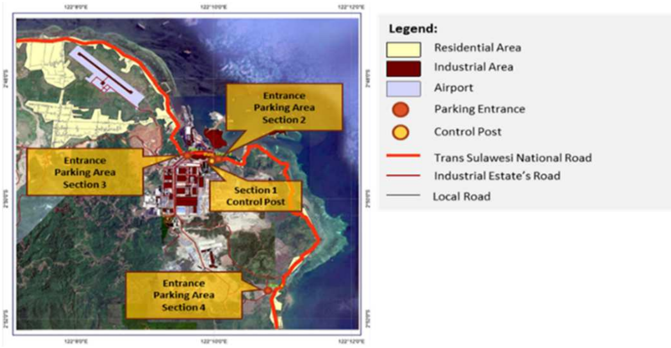

Fig. 3 Morowali Industrial Park and Trans Sulawesi National Road

The simulation indicates that improving road capacity through the road widening strategy is adequate to cope with the current peak traffic volume. This result is in line with studies by Metz [24], Wibisono and Mahardi [39] and Ossokina et al [26] concluding that the road widening strategy improves traffic performance in the short run. However, Morowali Industrial Park is projected to respond to the growing demand for nickel as an essential battery element. The park plans to triple its employees to 100,000 in the coming years. This plan implies that traffic volume would increase threefold. Expanding road capacity would align with the Morowali Government's strategy to develop infrastructure and facilities to support industrial development, as stated in the Morowali Regency Spatial Plan 2019–2039. The road widening can only be effective in the short run. Figure 5 shows the VCR prediction for a scenario of a triple number of employees and road widening to 9 meters. Peak hour VCR would still exceed 1. Thus, the simulation shows that the road widening strategy would only effectively cope with the existing traffic problem.

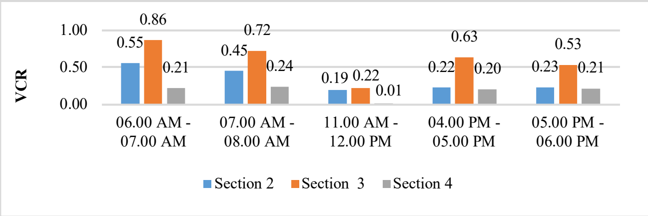

Fig. 4 VCR prediction: implementing a road widening strategy with 32,000 employees

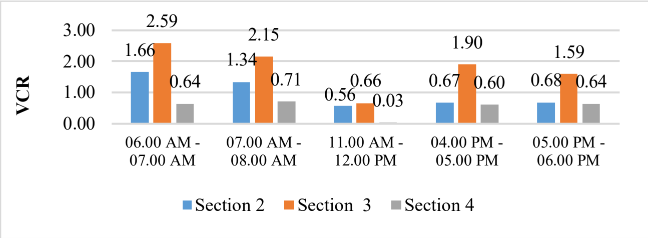

Fig. 5 VCR prediction: Implementing a road widening strategy with 100,000 employees

B. Demand Management

1) Time-shifting: Traffic congestion occurs when peak hour traffic concentrates in the same time and at the same road segment. The strategy of shifting working hours offers a better traffic distribution. Under the current arrangement, morning shift starting hours in Morowali Industrial Park are divided into four periods: 06.30 AM, 07.00 AM, 07.30 AM, and 08.00 AM. However, the proportion of workers in each period is distributed very much unevenly. Traffic counting shows that 07.00 AM is the busiest time, with 26,000 worker trips/hour. Meanwhile, the other periods vary, with a maximum of 11,000 trips/hour at 11:00 PM.

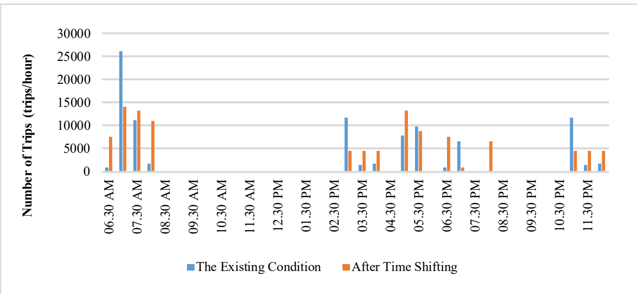

Fig. 6 Prediction of worker trips: before and after implementing time-shifting strategy

Time-shifting potentially reduces worker trip accumulation at the peak period, particularly at 07.00 AM. The shifted working times strategy applies to a more evenly distributed working trip volume. Figure 6 illustrates the distribution of workers' trips after time-shifting.

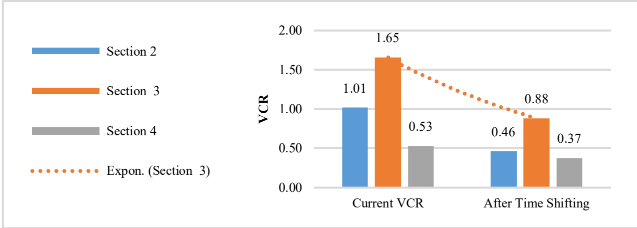

Fig. 7 VCR prediction: implementing a time-shifting strategy

By distributing the worker trip volume more evenly over each of the four periods, the VCRs are expected to decrease quite significantly. Figure 7 shows the calculation results of VCRs after time-shifting. Traffic volume is estimated to decrease to 650 pcu/hour at the densest road. VCR values on each road leading to all parking Sections are now less than 1. This finding aligns with studies by Achariyaviriya et al [27] and Ma et al [29], concluding that the time-shifting strategy overcomes congestion problems quite effectively.

2) Route-shifting: Time-shifting strategy is adequate to cope with the current traffic problem but would be ineffective in the longer term due to the increasing number of employees. Therefore, a route-shifting strategy is simulated by managing the workers' parking location. Developing new parking areas is the key to this route-shifting strategy since it redistributes traffic to more dispersed parking locations. Currently, the parking area Section 3, has the highest capacity, and most workers park their vehicles in this Section. This situation created the road leading to the parking area, Section 3, as the busiest one. An even worse traffic disturbance also happens on this road, since on-street parking and street vendors reduce the road's capacity, as shown in Figure 8.

Fig. 8 On-street parking around parking area section 3

The route-shifting strategy is targeted to deal with short-term and long-term traffic problems. As shown in Figure 9, developing a new 1.16 ha parking area in the northern industrial area (parking area Section 5) is targeted as a short-term strategy to reduce the parking accumulation in Section 3. This new parking area development is expected to stimulate two effects. Firstly, to disperse workers' trips to the road leading to the new parking section, which would reduce the traffic on the road leading to the parking area Section 3. Secondly, the new parking area Section 5 is expected to remove on-street parking at the road leading to Section 3, so the road would regain its ideal capacity.

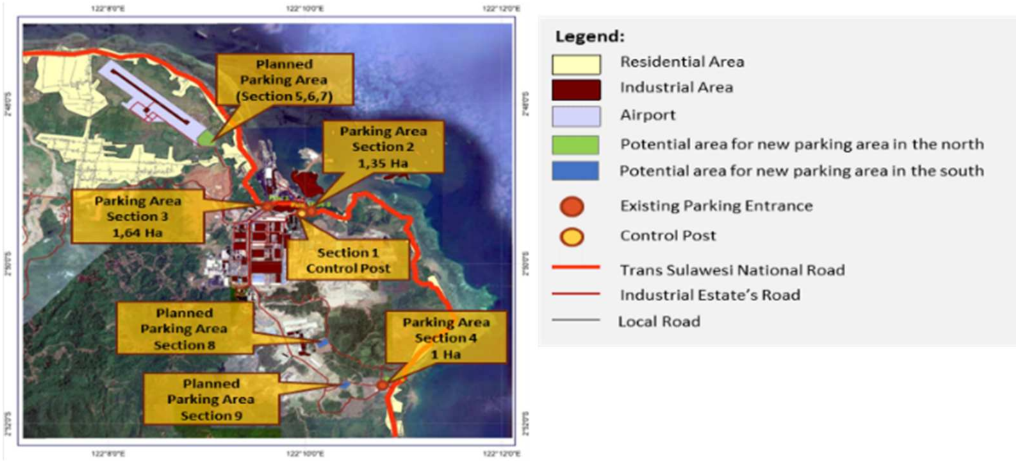

Fig. 9 Existing and planned parking areas

Table 1 presents the current supply-demand gap in parking areas in Morowali Industrial Park. The demand is derived from the traffic counting survey, while the supply represents the available capacity of three existing parking areas (1.35 ha in parking area Section 2; 1.64 ha in parking area Section 3; and 1 ha in parking area Section 4). The parking area, Section 1, is omitted since it is only a control post with extremely limited space. The calculation is based on motorcycle units since this is the predominant workers' trip mode in Morowali Industrial Park (94% of all vehicles). The locations of these parking areas are illustrated in Figure 9. The development of a new 1,16 ha parking area (Section 5) is realistic since Morowali Industrial Park owns 5,47 ha of available land in the northern area of this park.

TABLE I
GAP BETWEEN DEMAND AND SUPPLY OF PARKING AREA IN THE CURRENT CONDITION.

Parking Area	Demand (Motorcycle Units)	Supply Capacity of Parking Area (Motorcycle Units)	Gap	
			Parking Space Unit (Motorcycle Units)	Land Requirements (m^2)
Section 2	8,423	5,922	2,501	3,752
Section 3	8,843	7,700	1,143	1,715
Section 4	2,474	4,386	0	0
An additional parking unit is required for motorcycles			3,644	5,466
Car parking area (6% of total vehicles)				2,675
Circulation (30% of the total new planned parking area)				3,489
Total land requirements for the parking area section 5				11,630

Source: Traffic Counting and Morowali Industrial Park Development Plan

By shifting some workers' routes from parking area Section 2 and Section 3 to the new parking area Section 5, we could expect a significant traffic reduction on the road, particularly leading to parking area Section 3. Figure 10 shows the simulation results: Combining the time-shifting and route-shifting strategies could reduce the maximum VCR to around 0.65 at the densest road leading to the parking area, Section 3. Meanwhile, roads leading to Section 2, Section 4, and Section 5 are predicted to have VCRs of 0.46, 0.37, and 0.26, respectively.

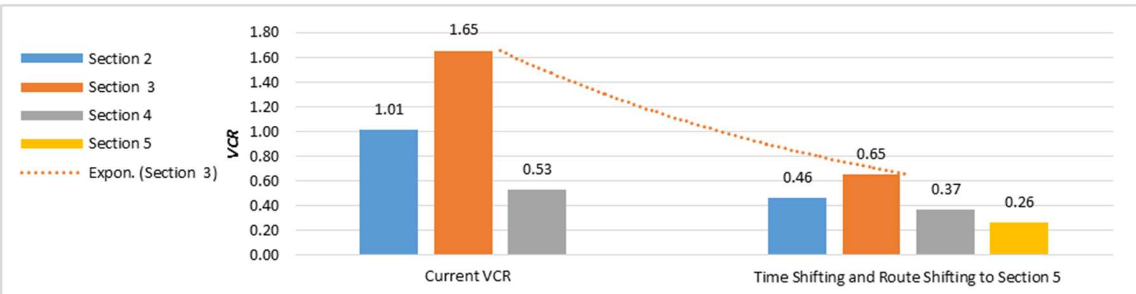

Fig. 10 VCR prediction: combining time-shifting and route-shifting strategies

However, shifting the workers' parking destination to the new parking area, Section 5, is effective only to fulfill the current short-term parking demand, not for the future 100,000 employees' parking demand. According to the parking demand-supply gap calculation, developing around 9.09 hectares of new parking area is necessary, which is divided into four areas (each around 2.27 hectares). It is also important to create different access roads to each new parking section to avoid traffic accumulation.

Figure 11 shows the simulation results. Developing the new four parking areas (Sections 6-9) is projected to distribute traffic volume and decrease VCR values to below 1 at all roads leading to those Sections. Assuming that the additional employees in the future are equally distributed to the new four parking areas, the VCR of Sections 6-9 was 0.85.

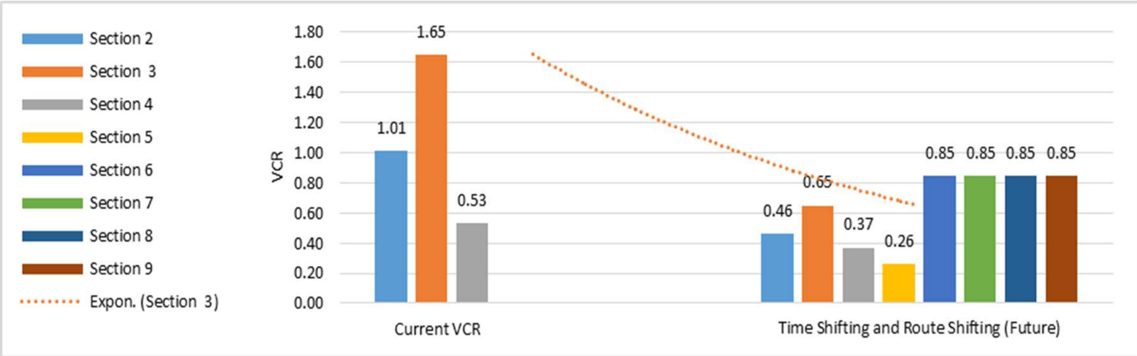

Fig. 11 VCR prediction: developing 4 new parking sections

In the northern part of the industrial Park, 5.47 ha of land is available to support the development of new parking areas, Sections 6 and 7. Since these two additional parking sections are located at the same lot as parking area Section 5, dividing them into three parking areas with different gates and different access roads is essential to avoid a single entry road access, which would even create a heavier traffic accumulation. It should also be noted that, to reduce the future traffic volume in the northern area, two new parking areas (sections 8 and 9) should be located in the southern region. This is to anticipate the future worker's trip origin, which is estimated to grow in the south of region due to the impact of intensified housing development in the area.

The simulation results of this "route-shifting-by managing parking location" strategy conclude a similar notion to that of Huang et al [36], who found that parking areas significantly influence people's travel, parking, and activity patterns. In the context of Morowali Industrial Park, we found that the route-shifting strategy alone is estimated to be effective only in tackling the current problem. However, a combination of time-shifting and route-shifting is much more effective in coping with future traffic escalation.

3) Mode-shifting: The strategy aims to reduce the total workers' trip volume by shifting some workers' mode choice from motorcycles to buses. A survey of 163 workers found that most workers use motorcycles due to the flexible service character of this mode and the lack of good public transportation services. Here, the simulation of the mode-shifting strategy is combined with the two previous strategies (time and route-shifting). The simulation applies to a 30% mode shift from motorcycles to employees' buses. The scenario of more than 30% mode-shifting is considered unrealistic, since the motorcycle's flexibility character would be the constraint.

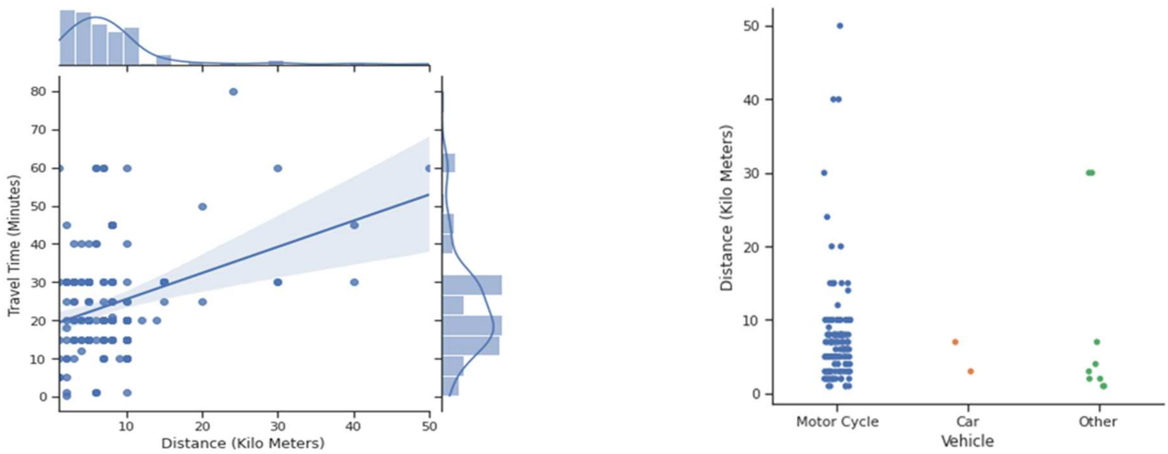

Fig. 12 Current workers' travel distance, time, and mode choice

A simulation results showed that based on 100,000 employees and the scenario of 30% of motorcyclists shifting to buses, it is estimated to reduce traffic volume in roads heading to parking sections 5, 6, 7, 8, and 9 and achieve a VCR value of around 0.25, as shown in Figure 13. The simulation calculates that five buses/hour/direction (capacity 30 seats/bus) are needed to implement this mode-shifting strategy.

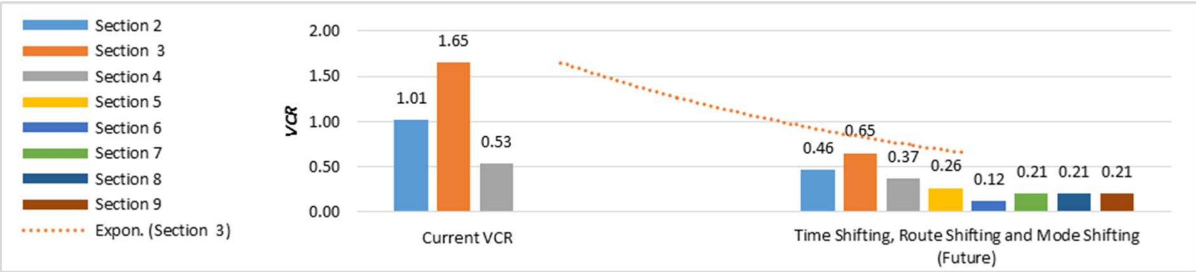

Fig. 13 VCR prediction: combining time-shifting, route-shifting, and mode-shifting strategies

The above simulation on demand management effectively reduces congestion in the short term. However, their long-term sustainability depends on continuous adjustments in industrial work schedules, parking policies, and public transport investment. Specifically, the respondent's response notes that the mode-shifting strategy should be supported by improving the quality of public transport service quality. The plan of the private-to-public mode-shifting strategy would only work with the support of better public transport service quality [40].

C. *Land Use Planning*

The organization of urban activities influences the transportation demand pattern [37]The land use planning strategy aims to create a more balanced worker trip demand pattern in the future. This section simulates the implementation of the strategy to estimate the impact of new housing development in the southern part of the Morowali Industrial Park on the future worker's trip distribution pattern.

Developing a context-specific land use planning strategy requires an understanding of employee characteristics. A survey of 163 workers revealed that 44% were single, younger than 30 years old, and lived in private rental accommodation concentrated in the northern part of Morowali, with a commute of under 10 kilometers (see Figure 14). These single employees live in private rental houses because the industrial park offers limited employee flats.

The concentrated workers' housing in the northern region of Morowali Industrial Park triggers severe traffic congestion because of the accumulation of workers' trips originating from the north. This study simulates a combined strategy of developing five new apartments (total capacity 9,000 workers) in the south with the four previous strategies. As shown in Figure 15, the simulation results show that we could expect VCR reduction to around 0.47 in the densest road leading to the parking area, Section 3, even when the employee size triples. The VCRs of all other roads leading to all other parking Sections are even better.

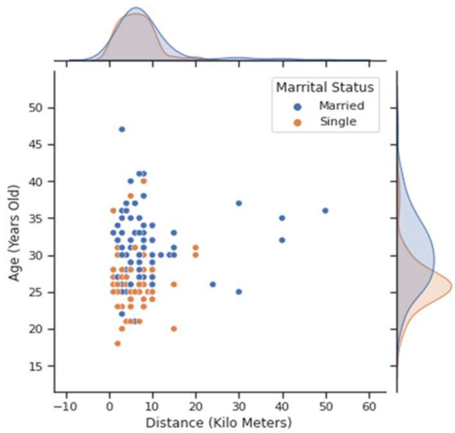

Fig. 14 Employees' age, marital status, and working trip distance: 163 respondents

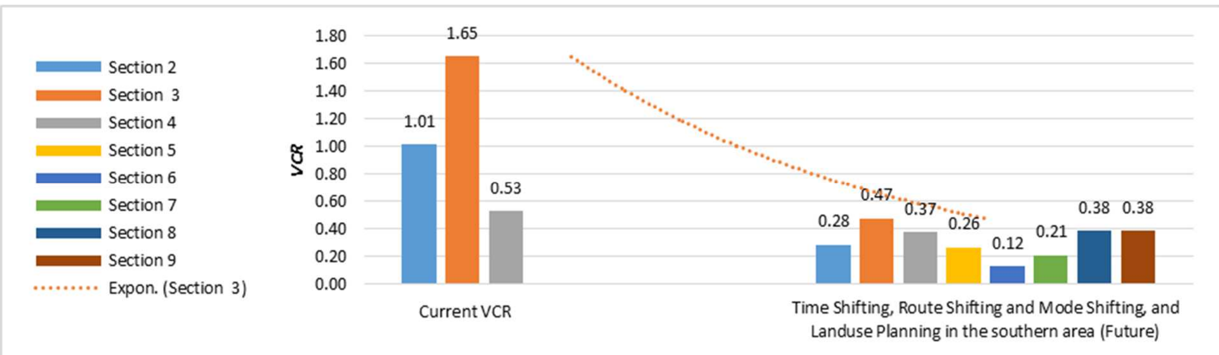

Fig. 15 VCR prediction: combining time-shifting, route-shifting, mode-shifting, and land use planning strategies

To conclude the benefits of implementing the five strategies, Figure 16 summarizes the potential VCR reduction. The figure shows that implementing the integration of the five strategies can best improve the traffic conditions in Morowali Industrial Park.

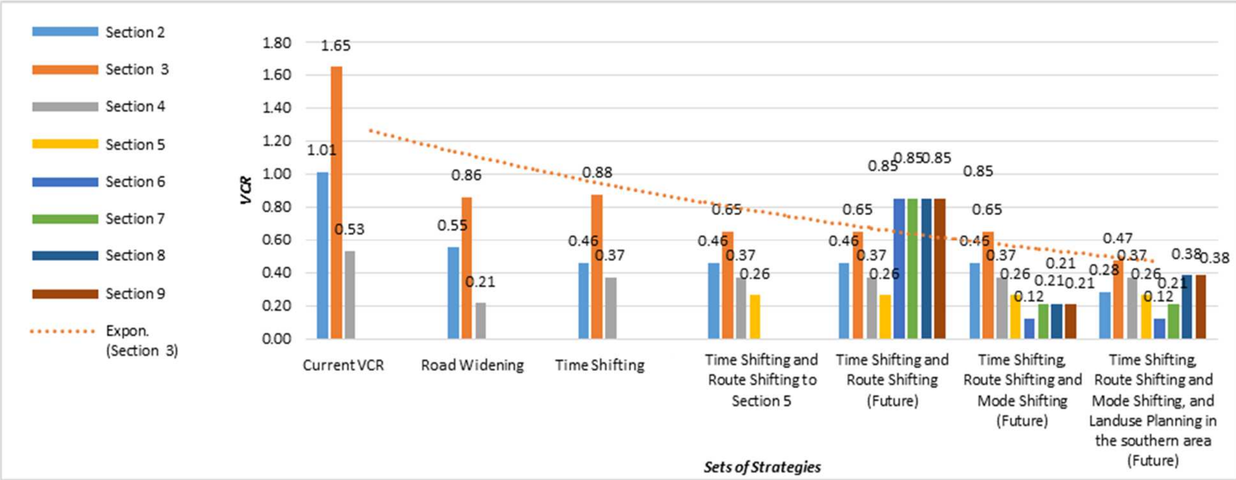

Fig. 16 VCR prediction: implementing integrated transportation strategies

D. Institutional Integration

Implementing an integrated transportation strategy would be complex without understanding its benefits among stakeholders and a clear division of responsibilities. In Indonesia's case, a decentralized governance system hinders this objective [41]. Asymmetric information regarding the benefits of the integrated transportation strategy is the major constraint for strong collaboration among stakeholders. One party might not support collaboration due to incomplete information, disregarding the broader context. Identifying the costs and benefits of the integrated transportation strategy would be difficult whenever stakeholders' decision-making faces imperfect information. This problem could be even worse when planned outcomes are difficult or costly to measure [42]. Two seminars were conducted to handle this constraint by communicating the situation, the problem, the potential benefit of the integrated strategy, and the proposed scheme of "stakeholders' division of responsibilities". The seminar involved the representatives of the central government (Ministry of Public Works and Housing), local governments (Central Sulawesi Province, Morowali Regency), Indonesia Morowali Industrial Park Managers and Developers, and an expert.

Through an interactive process, the seminars effectively built up a common understanding of the importance of collaboration for the success of the proposed integrated transportation strategy. Our findings confirmed that clear stakeholder roles and responsibilities reduced planning conflicts and promised efficient implementation. This proves that the success of an integrated transportation strategy relies heavily on institutional coordination and inter-agency collaboration. This result aligns with previous studies in transportation in general, emphasizing the importance of institutional and governance in transportation planning [5], [6], [43].

In the future, we propose to include the local community and representatives of residents who live around the industrial area in the land use planning, giving input to the local government to synchronize the industrial park with the residential areas surrounding it. Figure 17 shows the consensus on the agreed-upon division of responsibility for implementing the strategy.

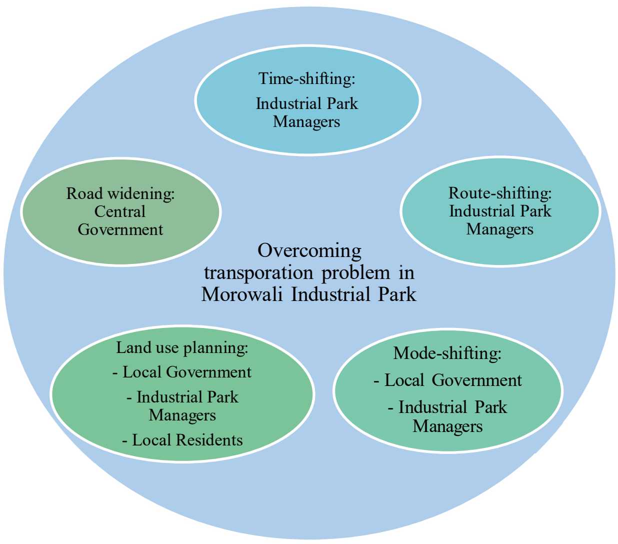

Fig. 17 Division of responsibility plan

IV. Conclusion

An integrated transportation strategy is required to cope with the typical growing externalities of industrialization in developing countries. At the fundamental level, many industrial park developments in Indonesia respond to the immediate market demand rather than being based on comprehensive and visionary planning. This planning failure creates many negative externalities, including in the transportation sector. This paper strongly suggests that the government should evaluate industrial park development plans to be more comprehensive and aware of negative externalities. By examining five strategies in the case of Morowali Industrial Park, Indonesia, this paper concludes that a transport supply management strategy through road widening would only be effective in overcoming traffic congestion in the short term.

However, the simulation demonstrates that a combination of demand management strategies (i.e., time-shifting, route-shifting, mode-shifting), and land use planning is potentially more effective. This integrated strategy could reduce the volume-to-capacity ratio on crucial roads. This reduction would facilitate the current and future workers' trip volume, which is projected to triple following nickel industry expansion. However, the success of the integrated transportation strategy depends significantly on strong coordination and collaboration among the executive agencies, i.e., the central government, the local governments, and the industrial park management.

A series of seminars helps share information and knowledge among the stakeholders. It built mutual understanding by providing symmetric information among stakeholders regarding the risk of externalities and the benefits of collaboration. A clear division of responsibility is crucial to encourage their willingness to participate proactively in implementing the strategy. These study-initiated seminars involve the central government, local government, experts, and Morowali Industrial Park managers and developers to include this institutional integration. However, these participants did not represent all the stakeholders involved in the practice. Therefore, for a future study, it is recommended to consider a more comprehensive set of stakeholders, including local residents who live near the industrial park and other wider communities whose activities are related to this area.

This study enhances our understanding of transportation planning. It contributes to its theory development by demonstrating that integrated strategies combining the management of supply, demand, land use, and institutional factors are more effective than single approaches. The institutional factor plays a crucial role in ensuring the success of strategy implementation. This finding aligns with urban transport governance theories, emphasizing the role of multi-stakeholder collaboration in transportation planning [22], [23], [35].

The VCR location in this case study can change over time depending on the policy dynamics set by local authorities and other influencing factors. However, this study provides an essential record of the traffic situation and future traffic prediction in Morowali Industrial Park, the world's largest producer of materials for electric vehicle batteries.

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