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Improving the Integration of Intermodal Transportation Services in the Poris Plawad Area in Tangerang City

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ABSTRACT

The integration of intermodal transportation services is a strategic necessity for improving the quality of urban transportation services. To realize the integration of services, it should be focused on the main transportation nodes in an area, such as Poris Plawad Terminal and Batu Ceper Station in the Poris Plawad Area, Tangerang City. This study aims to evaluate and determine strategies for improving the integration of intermodal transportation services in the Poris Plawad Area. The results of this study are expected to provide consideration for stakeholders to encourage the use of public transportation and realize the successful development of the Poris Plawad Area in the future. The sampling technique used was purposive sampling, with a total sample size of 202 respondents. Respondent data collection was carried out by distributing questionnaires to users of transportation services at Poris Plawad Terminal and Batu Ceper Station, as well as residents who are active within a radius of 800 meters from the terminal and station. This research uses the Importance Performance Analysis (IPA) and Theory of Inventive Problem Solving (TRIZ) methods. The results of the IPA analysis show that there are five service variables that are considered important but low-performing, so they need to be prioritized for improvement, including the provision of pedestrian crossing facilities, the provision of proper sidewalks, disturbance-free pavement quality, and access into and out of the node that is free from traffic conflicts. Recommended solutions based on TRIZ principles include building a sky bridge and closing the south entrance for access into and out of the station; building a sidewalk connected to the node that is built higher than the road surface and uses high-quality materials; placing sidewalk bollards; and permanently closing the station access point that passes through the railway level crossing. These improvements are expected to enhance accessibility, safety, and walkability, encouraging greater public transport use and aligning with the area's Transit Oriented Development goals.

1. Intoduction

Providing quality and satisfactory services is essential to building a strong relationship between service providers and users. By providing quality services, service providers can increase user satisfaction, retain existing users, and attract new users. In the context of urban transportation, the integration of intermodal services is a strategic necessity to improve the quality of transportation services. Intermodal transportation refers to a system that connects the various ways people or passengers move by land, air, sea, and rail in order to complete their journey as a whole. The focus on the integration of intermodal transportation services should ideally be applied to the largest transportation nodes in an area, such as Poris Plawad Terminal and Batu Ceper Station in the Poris Plawad Area, Tangerang City. The Poris Plawad area is also planned by the government to be developed as a Transit Oriented Development (TOD) area, which is regulated by government policies [1] [2] [3] [4]. To be designated as a TOD area, a transportation node must meet three considerations: the confluence of two or more mass transit corridors; an area that has or is expected to have high-value economic conditions; and being determined to be the center of activity in the area [5]. Infrastructure development plans at the terminal and station will also support the Poris Plawad area, including developing the TransJabodetabek route from Poris Plawad Terminal to Grogol as well as constructing LRT and MRT lines across Batuceper-Serpong.

Regarding the plan, the current condition of the area is not considered to fully represent the ideal TOD area because it is estimated that there is a gap between the conditions in the field and the principles of TOD area design. TOD should be applied to improve accessibility and mobility to create pedestrian-friendly areas and reduce the use of

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private vehicles by encouraging the use of public transportation [6]. Accessibility, especially in transit areas, is an important aspect of supporting the implementation of intermodal transportation in a city [7]. The most important aspects of intermodal integration include access, condition, and form of the transportation infrastructure network, node points, travel efficiency, transit costs, and operational factors [8]. The node points need to be well planned to accommodate the movement of pedestrians and vehicle users in the area.

This study aims to evaluate and determine strategies for improving the integration of intermodal transportation services in the Poris Plawad Area. The results of this study are expected to provide consideration for stakeholders in making decisions to improve integrated services and to achieve the successful development of the Poris Plawad area in the future.

2. Methods

This study uses the IPA (Importance Performance Analysis) and TRIZ (Teoriya Resheniya Izobreatrlskikh Zadatch, or Theory for Inventive Problem Solving) methods. The IPA method is used to evaluate the quality of services that have not met the user's expectations. Service quality is assessed based on user perceptions, which generate a diagram to visualize the position of variables that affect service user satisfaction [9]. The diagram is divided into four quadrants, shown in Figure 1, each representing the position of variables based on two dimensions: importance and performance. Importance refers to the level of importance or user expectations for a particular variable, while performance refers to how well a variable's performance meets user expectations.

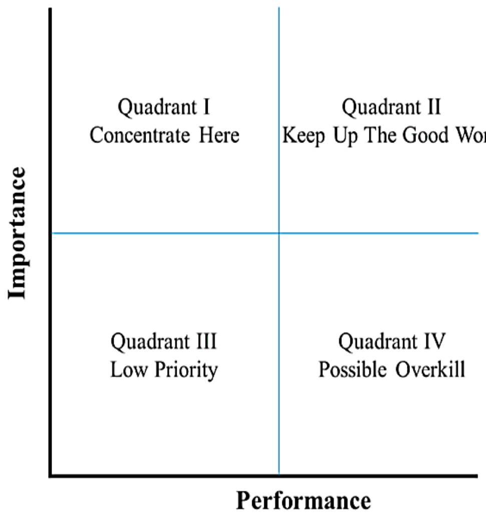

Figure 1. The IPA matrix diagram.

In this study, the IPA method uses a 4-point scale assessment with the following criteria, first, Importance, with a score of 1 = not important, 2 = less important, 3 = important, and 4 = very important. Second, performance, with a score of 1 = dissatisfied, 2 = less satisfied, 3 = satisfied, and 4 = very satisfied.

Meanwhile, TRIZ is used to design problem-solving through a structured problem approach so as to generate more optimal and innovative solution recommendations [10] [11] [12]. The TRIZ method is used in industry to replace the unsystematically of trial and error methods in solving problems [13]. TRIZ involves four analysis stages, shown in Figure 2.

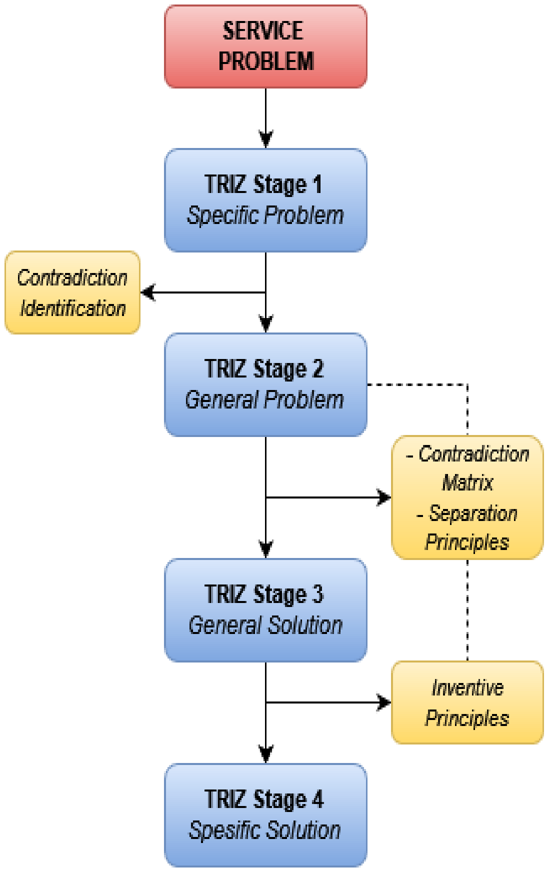

Figure 2. TRIZ Flowchart

Specific problem specification: This stage explains the specific causes of the problem by depicting the cause-effect relationship of the problem that needs to be improved, as well as the contradictions that arise in the problem. Contradiction refers to a situation where efforts to fulfill or improve one aspect of a need may interfere with, hinder, or decrease efforts to fulfill another aspect of the need.

TRIZ general problem: This stage involves formulating technical contradictions using the 39 parameters of the contradiction matrix and 4 separation principles to reduce or eliminate the physical contradiction, thereby obtaining suitable solution principles for the problem at hand. 4 separation principles, consisting of: time separation principle, space separation principle, scale separation principle, and condition separation principle

TRIZ general solution: This stage involves interpreting the principles of the obtained solution. These solution principles refer to the 40 inventive principles shown from the intersection of parameters in the contradiction matrix. Each intersection in the contradiction matrix will generate 1–4 solution principles.

Specific solution specification: This stage explains the specific solution to the problem by determining the most appropriate and relevant solution principles to be applied, considering factors such as technology requirements, cost, time, and possible environmental and social impacts.

To determine the required sample size, the Slovin formula is used with a standard error set at 10%. The sampling technique used is purposive sampling [14], with a total sample size of 202 respondents. Data is collected by distributing questionnaires to transportation service users at the Poris Plawad Terminal and Batu Ceper Station, as well as residents who have activities within an 800-meter radius of the terminal and station [15] [16] [17]. The design of the research questionnaire variables was reviewed based on the 14 component variables of the Global Walkability Index (GWI) [18], and the 9 parameters developed by the CAI-Asia Center (modified GWI) [19], as well as similar aspects or variables of previous research approaches [20] [21] [22] [23] [24]. Based on the collected data, 3 aspects of services were determined to be measured: accessibility and connectivity, comfort and attractiveness, and safety and security. The three aspects were then explored one by one, resulting in 20 research variables to be used in the form of questionnaire questions.

3. Result and Discussion

3.1 Importance Performance Analysis (IPA)

In this analysis, the results of the calculation of importance (I) and performance (P) scores are obtained as shown in Table 1. Additionally, it is also known that the average importance ($\bar{I}$) and average performance ($\bar{P}$) scores for all variables are 3,38 and 2,45, respectively. The mapping of variables from the IPA result in Figure 3 is can be seen in Table 2.

Table 1. Importance and performance score.

Variable	ΣI	$\bar{I}$	ΣP	$\bar{P}$
X1	684	3,39	547	2,71
X2	700	3,47	375	1,86
X3	613	3,03	364	1,80
X4	619	3,06	367	1,82
X5	707	3,50	607	3,00
X6	701	3,47	566	2,80
X7	704	3,49	632	3,13
X8	686	3,40	590	2,92
X9	685	3,39	386	1,91
X10	696	3,45	524	2,59
X11	690	3,37	607	3,00
X12	693	3,43	372	1,84
X13	688	3,41	560	2,77
X14	684	3,39	527	2,61
X15	695	3,44	362	1,79
X16	690	3,42	415	2,05
X17	632	3,13	378	1,87
X18	696	3,45	552	2,73
X19	706	3,50	598	2,96
X20	703	3,48	575	2,85
Total	13672	67,68	9904	49,03
Average		3,38		2,45

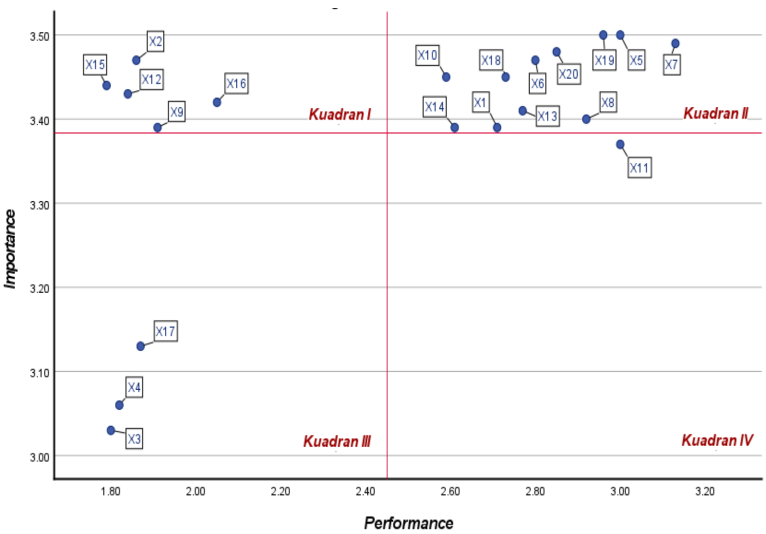

Figure 3. The IPA matrix diagram.

Table 2. The IPA variables mapping.

Quadrant	Variable	Description
I	X2	Availability and connectivity of pedestrian paths (sidewalks)
	X9	Quality of sidewalk pavement
	X12	Presence of disturbances to sidewalk function
	X15	Availability of pedestrian crossing facilities
	X16	Access into and out of the nodes is free from traffic conflicts
II	X1	Proximity of walking distance to the nearest bus stop
	X5	Connectivity and regularity of schedule information
	X6	Availability of directional signage and wayfinding facilities
	X7	Ease of obtaining public transportation tickets
	X8	Implementation of fares and payment methods
	X10	Availability of shelter and waiting facilities for public transport
	X13	Availability of drainage
	X14	Availability of disability-friendly facilities
	X18	Availability of traffic control facilities (markings, signs, and traffic lights)
	X19	Availability of surveillance cameras (CCTV)
	X20	Availability of lighting facilities
III	X3	Availability and connectivity of bicycle lanes
	X4	Availability of bicycle parking and/or bicycle rental
	X17	Availability of sidewalk guardrails
IV	X11	Availability of trash bins

Based on Figure 3, the IPA results for each quadrant are as follows, first quadrant I (concentrate here). Quadrant with high importance and low performance. There are 5 variables that are known to be the top priority to be improved because they are considered important or expected by service users, but the service performance is still low, so the perceived satisfaction is also low. These variables are X2, X9, X12, X15, and X16.

Second, Quadrant II (keep up the good work). Quadrant with high importance and high performance. There are 11 variables that are known to be needed to maintain service performance because they are in accordance with interests or expectations to provide satisfaction to service users. These variables are X1, X5, X6, X7, X8, X10, X13, X14, X18, X19, and X20.

Third, quadrant III (low priority). Quadrant with low importance and low performance. There are 3 variables that are known to be low priorities for improvement because they are considered less important to service users. These service variables result in low performance, so perceived satisfaction is also low. These variables are X3, X4, and X17.

Fourth, quadrant IV (possible overkill). Quadrant with low importance and high performance. There is 1 variable that is considered to be possibly excessive because the satisfaction from the service performance received by service users is too high compared to the importance of this variable. The variable is X11.

3.2 TRIZ (Theory of Inventive Problem Solving) Analysis

In this analysis, the problem-solving design is focused on 5 service variables in quadrant I as priorities for service improvement. To make it easier to identify problems and contradictions that occur, the 5 variables need to be simplified based on the object of the problem. The problem object is shown in Table 3.

Table 3. Problem object.

No	Variable	Service Problem Object
1.	Availability of pedestrian crossing facilities	Pedestrian crossing facility
2.	Availability and connectivity of pedestrian paths (sidewalks)	Sidewalk
3.	Presence of disturbances to sidewalk function	Sidewalk
4.	Quality of sidewalk pavement	Sidewalk
5.	Access into and out of the nodes is free from traffic conflicts	Node entry and exit access

Table 4. Formulation of pedestrian crossing facility contradiction matrix.

No.	Contradiction Parameter	Contradiction Matrix	Contradiction to Solve	
			No	Inventive Principle
1.	Feature to improve: Length of moving object Feature to preserve: Object-affected harmful	3 X 30	1	Segmentation
			15	Dynamics
			17	Another Dimension
			24	Intermediary
2.	Feature to improve: Productivity Feature to preserve: Area of moving object	39 X 5	10	Preliminary Action
			26	Copying
			34	Discarding and Recovering
			31	Porous Materials

Pedestrian crossing facility. The problem-solving design is as follows, first, problem identification: how to provide an effective and efficient pedestrian crossing facility without compromising the security, safety, and comfortability of the users. The Contradiction are the need to provide an accessible and efficient pedestrian crossing facility with the available space or land between the terminal and the station. The need to provide a comfortable and safe pedestrian crossing facility with the need to maintain the flow of vehicle traffic in the terminal and station areas. To formulate the relevant technical contradictions of the problem, a contradiction matrix is used, as shown in Table 4.

Based on Table 4, the selection of the contradiction parameter "length of moving object" is based on the need for an accessible, comfortable, and efficient pedestrian crossing. The "length of moving object" parameter in this context relates to the length of the moving object, pedestrians. The length referred to here is defined as the number or queue of pedestrians. The length of pedestrians can affect several aspects of designing an accessible, comfortable, and efficient crossing, which can be explained as follows.

First, pedestrian length can affect the accessibility of the pedestrian crossing. If pedestrians have a greater length, such as in the case of people with special needs or wheelchair users, the pedestrian crossing should be designed to be easily accessible. Doing so will allow users with various physical needs to easily cross the road safely and comfortably.

Second, Pedestrian length also affects the capacity of the pedestrian crossing. If the moving object (a pedestrian) has a large length, the pedestrian crossing should be designed in such a way that it can accommodate a larger number of pedestrians efficiently. This prevents congestion and improves the flow of pedestrian traffic.

Third, Pedestrian length can affect the efficiency of the crossing. If the moving object has a large length, the time required to cross the road will be longer. Therefore, the pedestrian crossing should be designed so that the crossing time can be minimized, taking into account the length of the moving object and the optimal speed of the pedestrian.

Meanwhile, the selection of the contradiction parameter "object-affected harmful" is based on the need to maintain smooth traffic flow. The selection of the "object-affected harmful" parameter relates to the affected object and the degree of harm it may cause to the smooth flow of traffic. Affected objects may refer to vehicles, pedestrians, or other elements in the traffic environment. Affected objects can cause harm if they are not properly regulated. For example, if there is an inefficient or unsafe pedestrian crossing, it may cause pedestrians to cross the road irregularly, which increases the risk of accidents and impedes traffic flow, which means a decrease in vehicle speed. In addition, if an object falls on the road or is blocked in the middle of the lane, the presence of physical obstructions or obstacles or poor road conditions can also disrupt the smooth flow of traffic and increase the risk of accidents.

Furthermore, the selection of the contradiction parameter "productivity" is based on the productivity that will be affected by providing an accessible, convenient, and efficient crossing path. The selection of the "productivity" parameter relates to how the design and implementation of the crossing can increase productivity in the implementation of an activity. Productivity here includes the efficient use of resources, time, and effort involved in optimal traffic management and the reduction of crossing times to improve convenience and accessibility, which can be explained as follows.

First, improving productivity in the context of pedestrian crossings can involve arrangements that facilitate access for users. For example, using designs that enable accessible, fast, and efficient crossings for pedestrians by reducing physical barriers or the distance to be travelled and accommodating a wide range of users, including those with special needs such as people with disabilities or wheelchair users, will increase the productivity of pedestrian crossing users in terms of time spent crossing the road by facilitating smooth traffic flow for pedestrians.

Second, in the case of pedestrian crossings, this could include proper placement and arrangement of traffic and road markings, the use of intelligent traffic signals, or automated crossing systems that help time the crossing. The use of appropriate technology can reduce waiting time and improve crossing efficiency, resulting in increased user productivity.

Third, Pedestrian crossing design that includes factors such as adequate lighting, protection from extreme weather, clear signs and signals, or other supporting facilities can improve the comfort and productivity of pedestrian crossing users and provide a better experience.

Meanwhile, the contradiction parameter "area of moving objects" is based on the availability of space or land between the terminal and station. The selection of the contradiction parameter "area of moving objects" is related to productivity, which leads to the optimal use of space. For example, considering a significant number of pedestrians and high traffic levels, it is necessary to plan a crossing design that provides direct access and minimal travel distance for pedestrians to cross the road efficiently. In a limited space, such as in dense urban areas, it is important to maximize the use of the available space for the pedestrian crossing.

To reduce or eliminate the physical contradictions of the problem, 4 separation principles are used, consisting of, first, time separation principle, which separates the time between vehicle and pedestrian traffic. Second, space separation principle, which separates the space used by pedestrians and vehicles. Third, scale separation principle, which increases or decreases the scale of the elements involved in the contradiction of providing pedestrian crossing facilities. Fourth, condition separation principle, which separates the conditions of pedestrian crossing facilities with the arrangement of vehicle traffic and pedestrian traffic.

With Table 4 and the separation principles as a guide, the principles that could be used and were relevant to being used were chosen: principles 1, 10, 17, and 34. The other 4 principles were not used because they were not relevant (i.e., they did not have a description of the improvement solution). The identification of proposed improvements is explained in Table 5.

Table 5. Identification of proposed improvements to crossing facilities.

No.	Inventive Principles	
1.	Principle Interpretation	#1. Segmentation Divide pedestrians and vehicles into separate segments by constructing pedestrian bridges separate from the road or creating an underpass connecting the terminal and station so that pedestrians can cross safely without disturbing traffic flow.
2.	Principle Interpretation	#17. Another dimension Build pedestrian bridges that can be easily and comfortably accessed by pedestrians via stairs, escalators, or elevators.
3.	Principle Interpretation	#10. Preliminary action Reduce vehicle speeds at pedestrian crossing areas by setting traffic lights or signs to give priority to improving pedestrian safety.
4.	Principle Interpretation	#34. Discarding and recovering Temporary traffic engineering with different lane settings (diversion of traffic flow) or restrictions on vehicle access at certain times to provide a wider and safer crossing area while maintaining the flow of vehicle traffic.

Sidewalk, the problem-solving design is as follows problem identification: how to provide sidewalks that meet the following 3 mains are: the need to provide proper sidewalks to ensure accessibility and mobility that are comfortable and safe. The need to provide good-quality and durable pavement to provide comfort and safety. The need for sidewalk functions that are free from disturbances that can reduce comfort and safety.

The Contradiction are the need to provide sidewalks that are built to a reasonable width depends on the availability of space or land along the road. The need to provide safe and comfortable sidewalk pavement with the quality of materials used. The need for safe and comfortable sidewalk function with the possibility of disturbance from the surrounding area. To formulate the relevant technical contradictions of the problem, a contradiction matrix is used, as shown in Table 6.

Table 6. Formulation of sidewalk contradiction matrix.

No	Contradiction Parameter	Contradiction Matrix	Contradiction to Solve	
			No	Inventive Principle
1.	Feature to improve: Area of stationary Feature to preserve: Object-generated harmful	6 X 31	22	Blessing in disguise
			1	Segmentation
			40	Composite material
2.	Feature to improve: Ease of repair Feature to preserve: Reliability	34 X 27	11	Beforehand cushioning
			10	Preliminary action
			1	Segmentation
			16	Partial or excessive actions

Based on Table 6, the selection of the contradiction parameter "area of stationary" is based on the need to provide sidewalks built with a width that is feasible with the availability of space or land along the road. The selection of the "area of stationary" parameter relates to the area of stationary areas in the context of sidewalks. This parameter relates to the design and management of sidewalks that allow optimal use of available space or land. A proper sidewalk area is important to provide pedestrians with sufficient space, including room to walk, stop, and move safely. A proper sidewalk area also contributes to freedom from obstruction. A sidewalk area that is limited or full of obstacles, such as parked vehicles or vendors, will disrupt pedestrian flow and cause discomfort. Pedestrians will feel confined and trapped between people or obstacles. Providing sufficient sidewalk width and freedom from obstruction is necessary for an optimal pedestrian environment. In areas of limited space or land, such as dense urban areas, it is important to maximize the use of available space to provide sidewalks of proper width.

Meanwhile, the selection of the contradiction parameter "object-affected harm" is based on the need to ensure convenient and safe accessibility and mobility for pedestrians. The selection of the "object-affected harmful" parameter relates to objects that are potentially affected harmfully. A proper sidewalk should be designed to reduce the risk of accidents or injuries caused by harmful objects, such as large holes, dangerous cracks, or slippery surfaces. A proper sidewalk should also be free of obstacles such as improperly parked vehicles, physical barriers or obstructions blocking the path, or merchandise narrowing the walking space. In addition, sidewalk design should consider pedestrian safety with safe traffic arrangements, such as clear separation between sidewalks and roads or the use of warning signs to avoid collisions with vehicles. In the selection of the contradiction parameter "object-affected harmful", it is important to involve regular care and maintenance of the sidewalk to ensure that the sidewalk condition remains safe, hassle-free, and of good quality.

Furthermore, the selection of the contradiction parameter "ease of repair" is based on the need to provide safe and comfortable pavements with quality materials. The selection of the "ease of repair" parameter relates to the level of ease in making repairs to the pavement in the event of damage. Ease of repair plays an important role in ensuring that the repair process does not disturb pedestrians. Ease of repair can influence the selection of materials used for the pavement. The selection of high-quality materials for pavements is essential to ensuring durability and longevity. However, no material can last forever without deteriorating over time. If there is damage to the pavement, such as cracks or potholes, easily repairable pavement materials will allow repairs to be carried out quickly without disrupting the access and comfort of pavement users. This reduces the risk of slips, falls, or injuries, keeping the sidewalk safe for pedestrians. With ease of repair, sidewalk pavements can also be well maintained and remain in optimal condition.

Meanwhile, the selection of the contradiction parameter "reliability" is based on the quality of the materials used. The selection of the "reliability" parameter relates to the reliability or durability of the materials used in the pavement. The selection of the right materials can help fulfill the need to provide durable and high-quality pavements. Good materials will have sturdy physical properties and withstand weather conditions, moisture, wear and tear, pressure, and traffic demands. By using reliable materials, the pavement can have a longer life and be resistant to damage. In addition, the selection of the "reliability" parameter is also related to good construction methods that comply with technical standards. The correct construction process will ensure the quality and reliability of the pavement.

To reduce or eliminate the physical contradictions of the problem, 4 separation principles are used, consisting of time separation principle, which separates time by applying different pavement repair or maintenance times. Then, space separation principle, which separates the space between pedestrians and vehicle traffic. Scale separation principle, which is to increase or decrease the scale of the elements involved in the contradiction of sidewalk provision. Last, condition separation principle by changing the conditions or environment along the sidewalk.

With Table 6 and the separation principles as a guide, the principles that could be used and were relevant to being used were chosen: principles 1, 10, 11, 16, and 40. The other principles were not used because they were not relevant (i.e., they did not have a description of the improvement solution). The identification of proposed improvements is explained in Table 7.

Node entry and exit access. The problem-solving design is as follows: Problem identification: how to provide safe and controlled access for pedestrians, vehicle users, and trains in the presence of railway level crossings without automatic gates. Then, the contradiction are the need to provide safe and convenient access into and out of the railway station, with the need to maintain traffic flow and avoid creating traffic disturbances around the railway level crossing, and the need to provide easy and fast access into and out of the railway station while maintaining the safety of vehicle users and pedestrians. To formulate the relevant technical contradictions of the problem, a contradiction matrix is used, as shown in Table 8.

Based on Table 8, the selection of the contradiction parameter 'area of moving objects' is based on the need to provide easy, fast, and safe access into and out of the train station. The selection of the parameter "area of moving objects" relates to the area used for the movement of objects, in this case, the movement of passengers, vehicles, and trains in the station area. In terms of the area of moving objects, it involves the regulation and control of traffic in the railway station area. Separation of passenger, vehicle, and train traffic flow is required at the entrance and exit of the railway station. For example, using separate lanes for arrivals and departures, optimizing the placement of entrances and exits, or utilizing traffic control technologies that can facilitate smooth flow.

Table 7. Identification of proposed improvements to sidewalk

No.	Inventive Principles	
1.	Principle Interpretation	#1. Segmentation Separating pedestrian and vehicle paths with the use of barriers and warning signs, e.g., installing bollards or guardrails to avoid parking vehicles on sidewalks.
2.	Principle Interpretation	#10. Preliminary action To provide regular maintenance and repairs to the sidewalks to avoid greater damage in the future that requires longer repair times and disturbs the function of the sidewalks. In addition, it can combine the sidewalk function with solar street lighting to improve pedestrian safety.
3.	Principle Interpretation	#11. Beforehand cushioning Adding impact-absorbing cushions to the sidewalk to reduce the risk of severe injury when an out-of-control vehicle leaves the roadway.
4.	Principle Interpretation	#16. Partial or excessive actions Putting warning signs around the sidewalk can reduce the possibility of vehicle collisions. Also, it can make sidewalks wider in areas with high pedestrian density and narrower in lower-density areas.
5.	Principle Interpretation	#40. Composite material Combining two or more material components to create a new solution, for example, by using cheaper materials but reinforced with a combination of other materials to improve pavement quality.

Table 8. Formulation of node entry and exit contradiction matrix.

No	Contradiction Parameter	Contradiction Matrix	Contradiction to Solve	
			No	Inventive Principle
1.	Feature to improve: Area of moving object Feature to preserve: Speed	5 X 9	29 30 4 34	Pneumatics and hydraulics Flexible shells and thin films Asymetry Discarding and recovering
2.	Feature to improve: Area of moving object Feature to preserve: Object-affected harmful	5 X 30	22 33 28 1	Blessing in disguise Homogeneity Mechanical substitution Segmentation

Meanwhile, the selection of the contradiction parameter "speed" is based on avoiding traffic disturbances around railway level crossings. The selection of the "speed" parameter relates to the speed or smooth movement of passengers, vehicles, and trains in the station area by involving effective traffic engineering around level crossings. By considering the speed of vehicles, signal settings can be designed to provide sufficient time for vehicles to safely pass through the crossing. The use of appropriate warning signs, road markings, or signal lights can help regulate the flow of vehicular traffic, avoid the generation of traffic disruptions, and ensure safety at level crossings. Taking into account the speed of pedestrian traffic, the use of safe crossing facilities can help avoid traffic disruptions and maintain pedestrian safety compared to level crossings.

The selection of the contradiction parameter "object-affected harmful" is based on the need to maintain the safety of vehicle users and pedestrians. The selection of the "object-affected harmful" parameter relates to harmful objects such as vehicles or pedestrians that are near a railway level crossing, which can be a risk factor and potentially jeopardize safety. The selection of the object-affected harmful parameter involves lane separation and good traffic management around the railway level crossing. For example, building pedestrian bridges or underpasses or using flyovers or underpasses for vehicles can help reduce the risk of dangerous interactions between vehicles, pedestrians, and trains. Good traffic arrangements, such as signal lights, traffic signs, or traffic control officers, are also important to ensure safety at railway level crossings. In addition, it involves the implementation of effective warning and surveillance systems around railway level crossings. For example, the use of warning signs, signal lights, or automatic crossings can help alert pedestrians and vehicle users.

To reduce or eliminate the physical contradictions of the problem, 4 separation principles are used, consisting of first, time separation principle, which separates the time between access into and out of the railway station through level crossings by making different operational time schedules. Second, space separation principle, which separates the space between access into and out of the railway station and the railway track. Third, scale separation principle, which is to increase or decrease the scale of the elements involved in the contradiction of providing access into and out of the railway station. Fourth, Condition separation principle, which is to change the conditions of the level crossing by adding proper safeguards.

With Table 8 and the separation principles as a guide, the principles that could be used and were relevant to being used were chosen: principles 1, 4, 9, 28, and 34. The other 4 principles were not used because they were not relevant (i.e., they did not have a description of the improvement solution). The identification of proposed improvements is explained in Table 9.

Table 9. Identification of proposed improvements to access into and out of the node.

No.	Inventive Principles	
1.	Principle	#1. Segmentation
	Interpretation	Separate level crossings from roads by building an underpass or overpass.
2.	Principle	#4. Asymetry
	Interpretation	Separate the time for access into and out of the station through level crossings by creating a different operating time schedule between the train and pedestrians and vehicle users.
3.	Principle	#9. Preliminary anti-action
	Interpretation	Permanently close the access point into and out of the railway station that passes through the level crossing with a barrier wall, or reroute vehicle traffic to other roads.
4.	Principle	#28. Mechanical substitution
	Interpretation	The use of automatic gates, sensor systems and audiovisual warning devices that can provide warning signs to road users and train users before entering the level crossing area.
5.	Principle	#34. Discarding and recovering
	Interpretation	Placing temporary barriers on the entry and exit of vehicles passing through railway level crossings and rerouting vehicle traffic to other roads at certain times.

3.3 Discussion

3.3.1 Final Solution Proposed Improvement Strategy

To determine the most feasible final solution to implement, it is necessary to consider the following important things: Not all the TRIZ inventive principles can always work for problem-solving, and the interpretation of the principles should be done carefully with the right context in mind.

Each problem can have several different solutions. The selection of the right solution must be able to be applied easily and effectively to provide improvements to the problem at hand and consider sustainability aspects such as cost, time, and technology requirements, as well as environmental and social impacts that may be caused.

3.3.2 Recommendation

The recommended solutions are based only on the results of the TRIZ analysis that are considered most relevant in their implementation by considering the cost, time, and technology that may be required as well as the negative environmental and social impacts that occur to a minimum for the purposes of the development process. The recommended solutions are:

First, to solve the problem of providing pedestrian crossing facilities, it is necessary to provide special access by building a pedestrian bridge or sky bridge that directly connects the terminal building and the station building. To maximize functionality, it is also necessary to close the south door of the station entrance and exit, which is directly opposite the terminal exit access. Although it may reduce the efficiency of time and energy for service users, the level of security, comfort, and safety will be better. The construction of a sky bridge would also be less costly, faster to build, and use less complex technology. Service users who must enter the main building of the terminal and station to be able to use the pedestrian bridge or sky bridge can increase the economic turnover of traders in the terminal and station.

Second, to solve the problem of providing pedestrian paths (sidewalks), it is necessary to separate pedestrian and vehicle paths by building sidewalks that are higher than the road surface and placing sidewalk bollards. This aims to prevent rainwater from inundating the sidewalk and to prevent vehicles from parking on the sidewalk. Sidewalks should be constructed along at least an 800 meters radius that continues to connect to the node location. Sidewalks are built with proper width, equipped with shade or weather protection facilities, and equipped with lighting with solar electricity technology. Although it will require higher costs in the provision or construction of facilities, the availability of proper, safe, and comfortable sidewalks is expected to encourage people to walk more often, leave their private vehicles, and use public transportation. Avoid the use of cheap and non-durable materials for sidewalk pavement because it will only make the sidewalk quickly damaged, which eventually increases the cost of repair or maintenance. This can also potentially reduce public interest in walking if the condition of the sidewalk is quickly damaged, especially if damage has already occurred and is slow to be repaired.

Third, to solve the problem of providing access into and out of the node, it is necessary to permanently close the access points into and out of the station that pass-through level crossings with a barrier wall. The movement of people who want to go to the station will all be centralized through a pedestrian bridge or sky bridge through the terminal building. Meanwhile, the movement of private vehicles to get to the station can only go through the north entrance. Although it will reduce the efficiency of time and energy, the level of security and safety will be better. Closing the access points into and out of the station that pass through the level crossing permanently with a barrier wall is also easier, does not require large costs, and has a faster construction time. With the closure of the station entrance and exit access points that passthrough level crossings and the additional closure of station entrance and exit access at the south entrance, it is hoped that people will choose an easier way by going through the pedestrian bridge or sky bridge from the terminal by walking or using available public transportation to the terminal.

4. Conclusion

The government's plan to develop the Poris Plawad area as a Transit Oriented Development (TOD) area requires the provision of integrated transportation services supported by proper accessibility. The node needs to be well planned in order to accommodate the movement of pedestrians and vehicle users in the area. This is important to note in order to realize the success of the Poris Plawad area development plan in the future. Based on the results of the analysis, there are 3 service provision needs that must be prioritized at this time. First, the provision of pedestrian crossing facilities. Second, the provision of proper sidewalks, free of interference, with attention to the quality of the pavement. Third, access into and out of the node must be free from traffic conflicts. The solutions that can be recommended include the construction of a sky bridge connected between the terminal building and the station building and the closure of the southern access door into and out of the station. In addition, it is necessary to provide sidewalks connected to the terminal and station by being built higher than the road surface and using high-quality materials, placing sidewalk bollards, and permanently closing the station entrance and exit access points that pass-through level crossings. Implementing these strategies not only addresses immediate infrastructure deficiencies but also supports long-term TOD objectives by improving accessibility, encouraging modal shifts from private to public transport, and fostering a more walkable urban environment.

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