FUNCTIONAL DESIGN OF PHYSICAL INTERNET FACILITIES: A ROAD-BASED TRANSIT CENTER

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Abstract

In their 2010 IMHRC paper, Montreuil, Meller and Ballot proposed a set of facility types that would be necessary to operate a Physical Internet, which they termed "π-nodes." This paper is part of a three-paper series for the 2012 IMHRC where the authors provide functional designs of three PI facilities. This paper covers a road-based transit center, or road-based π-transit. The mission of a π-transit node is to enable the transfer of π-carriers from their inbound to outbound destinations. Therefore, a road-based π-transit provides a mechanism to transfer π-trailers from one truck to another. The objective of the paper is to provide a design that is feasible to meet the mission of this type of facility, identify ways to measure the performance of the design, and to identify research models that would assist in the design of such facilities. The functional design is presented in sufficient detail as to provide an engineer a proof of concept.

1 Background

The Physical Internet (PI) was presented by Montreuil [10] as a response to what he termed the *Global Logistics Sustainability Grand Challenge*. This grand challenge covered three aspects of sustainability: economic, environmental and social, using symptoms from today's logistics system as evidence of the unsustainability of our present system. The PI is defined as an open global logistics system founded on physical, digital and operational interconnectivity through encapsulation, interfaces and protocols. The PI enables an efficient and sustainable logistics web that is both adaptable and resilient.

The term, PI, employs a metaphor taken from the Digital Internet, which is based on routers, all transmitting standard packets of data under the TCP-IP protocol. A core enabling technology to make the PI a reality exploit is the encapsulation of goods in modular, re-usable and smart containers. This will make it possible for any company to handle any company's products because they will not be handling *products* per se. Instead they will be handling standardized modular containers, just as the Digital Internet transmits data packets rather than information/files.

Another enabling technology of the PI is an open standard set of collaborative and routing protocols. Modularized containers are much easier to route through transport networks as individual "black-box" loads instead of heterogeneous loads of different-sized cases and pallets. But the efficient routing of modular containers over a collaborative network can only be realized if there is a standard set of routing and digital protocols, as well as business and legal conventions that apply across a community of users.

And of course, handling and digital interfaces are needed to ensure reliability, security, and transparency as well as that the quality of the product being handled is not compromised through its movements. These interfaces cannot be proscribed, but the functional requirements need to be so that innovative interfaces may be developed.

A simplified mental image of the PI business model is to imagine an eBay-like freight transportation "auction" that handles "black-box" modular containers through an open and shared network with a vast community of users that utilize supplier ratings to drive logistics performance. This creates a multi-scale process where at the lowest level we have individual containers and at the highest level we have an international network of transportation, storage and services resources.

The PI was discussed extensively as part of the 2010 IMHRC held in Milwaukee. After an introduction of the PI by Montreuil [9], roundtable discussions focused on further defining the PI. As part of the poster session at the 2010 IMHRC, the first paper on PI facilities was presented and later published in *Progress in Material Handling Research: 2010* [11]. This paper proposed a set of facility types that would be necessary to operate a PI. Such facilities were termed "π-nodes." The complete set of π-nodes included: transit nodes, switches and bridges, hubs, sorters, composers, stores and gateways. The π-nodes vary in terms of purpose, scope and scale, as well as in terms of capabilities and capacities, yet they all have in common that they are explicitly designed to handle π-containers with respect to the physical, operational and informational protocols of the PI.

Although we believe this is a compelling vision for the future of logistics, there are a number of reasons why we cannot deploy the PI today. First, there is no agreed-upon standard for various container sizes outside of the international shipping containers. This, and the lack of standard contracts and other operational issues, means that collaborative distribution is difficult to initiate and maintain. And expanding collaborative distribution is limited by the fact that there is not a centralized exchange for freight based on a standardized specification of a load, with the lack of standardized specification of a load due to the lack of standard containers. Other circular arguments on the use of the rail system, due to the currently time-inefficient design of switch yards, the lack of innovation due to the difficulty in justifying innovation when what is handled is so diverse, and the inability to construct facilities that will act as the backbone of the PI until there are users of the PI, all mean that there are a number of research questions and business issues that must be addressed before the PI is to become a reality.

Current research on the PI is focused on a few of the many questions related to it. The three questions that have been investigated with completed or on-going projects are: 1) the design of PI facilities; 2) the impact of modular containers on shipped volume; and 3) the impact of open distribution webs.

After the 2010 IMHRC, Meller and Montreuil [8] were awarded a research contract from MHIA to investigate the impact of PI on facility and material handling system design. This chapter is the result of this project, presenting a conceptual design of a PI transit center. Figure 1 illustrates the role of this type of facility in a relay network. A project with Ballot, Glardon and Montreuil [1] examined issues related to bimodal road-rail hubs and studied how PI can help address these issues. A conceptual design of a bimodal road-rail π-hub is the second chapter in this series [3]. The third chapter in the series [12] presents a conceptual design of a distribution π-hub resulting from the MHIA project by Meller and Montreuil [8].

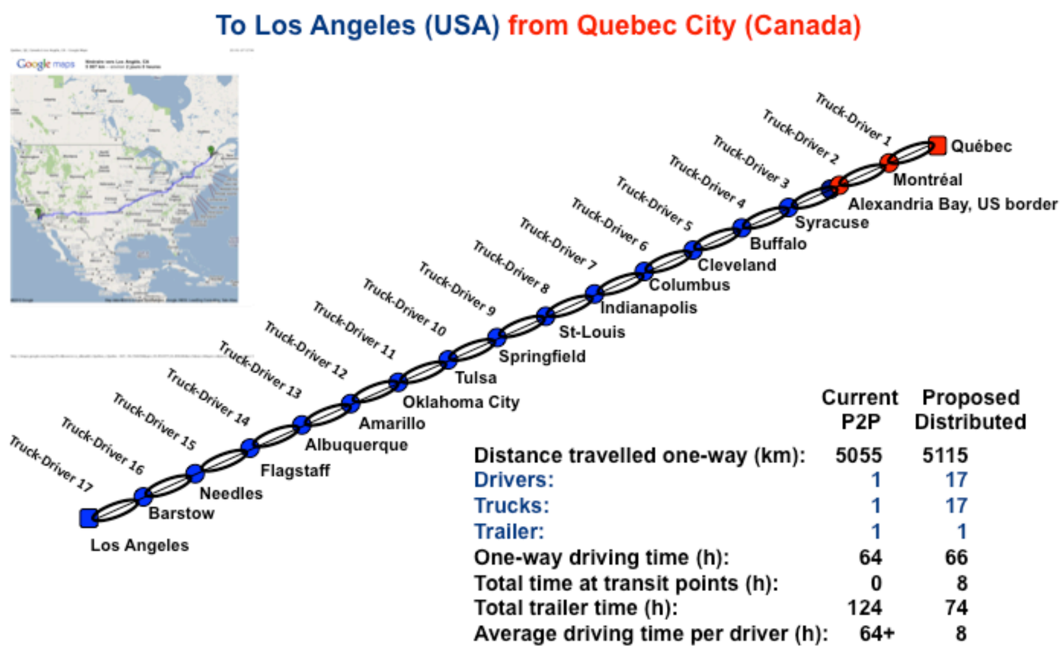

Figure 1: An Example of Product Distribution Speed Using a Relay Network.

As one of the key characteristics of the PI is encapsulation of goods in modular containers, Meller and Ellis [5, 6] are investigating the impact of these standardized modular containers on the amount of shipped volume. Although one of the concerns for moving to a PI was that limiting the choices on container sizes would increase the amount of shipped volume, as has been shown in [7], this is not likely an impediment to the PI, especially if the products are currently shipped on pallets. That is, although the shipped volume may increase as much as 10% at the case level, the shipped volume decreases by 10% at the pallet level if some flexibility is permitted in the number of items shipped per case.

The potential of the PI to address the Grand Challenge relates to how much waste can be removed from the system by sharing resources. Both the Meller and Ellis [6] and Ballot, Montreuil and Glardon [2] projects examine this question. Although their assumptions, data and methodology differ, both studies indicate that the miles driven and the CO_2 emissions can be cut by 25-50% with even a partial adoption of the PI.

In the next section we provide the mission of the road-based π-transit in more detail, which includes the design goals and key performance indicators (KPIs) that could be used to measure a design realization's performance. We also "close the loop" and discuss how such a facility would help achieve the Global Logistics Sustainability Grand Challenge. Then in Section 3 we provide a conceptual design of the facility as well as our design process. The objective of this section of the paper is to provide a functional design and a realization of the design that is feasible to meet the objectives of this type of facility. We will provide sufficient detail so as to provide an engineer a proof of concept, as well as provide values for the KPIs identified in Section 2. In Section 4, we conclude the paper with our thoughts on future research that would be valuable in assisting with the design of such facilities.

2 Mission of a Road-Based PI Transit Center

The mission of a road-based PI transit center, hereafter referred to as "π-transit," is to efficiently and sustainably transfer trailers from one truck to another to serve two purposes: 1) to enable the trailer to move from its origin to its destination to facilitate delivery within its delivery time window; 2) to enable a truck to pick up a trailer that will put the driver closer to his/her target destination at the end of his/her workday. This mission is illustrated in Figure 2.

Such a mission assumes that some basic information is part of the PI operating protocol. First, all trailers will depart from an origin location with the requirement to be delivered at a destination location within a delivery time window. The pickup at the origin location may or may not be part of the PI, but at some π-transit, the load enters the PI. Likewise, on the delivery to the destination location, there will be a preceding stop at a π-transit. Thus, these two π-transit nodes act as PI gateways and become the load's PI origin and destination.

Second, each driver in the PI will have a number of driver hours available for that day, which will be a function of governing hours of service requirements as well as company and individual requirements. In addition, each driver will have a target destination for the end of his or her workday.

Thus, when a trailer-driver pair signals its intention to visit a π-transit node, a negotiation protocol determines to which driver the trailer will be assigned to move it towards its PI-destination as well as to which trailer the driver will be assigned to move him/her towards his/her end-of-shift destination. The π-transit facilitates this process.

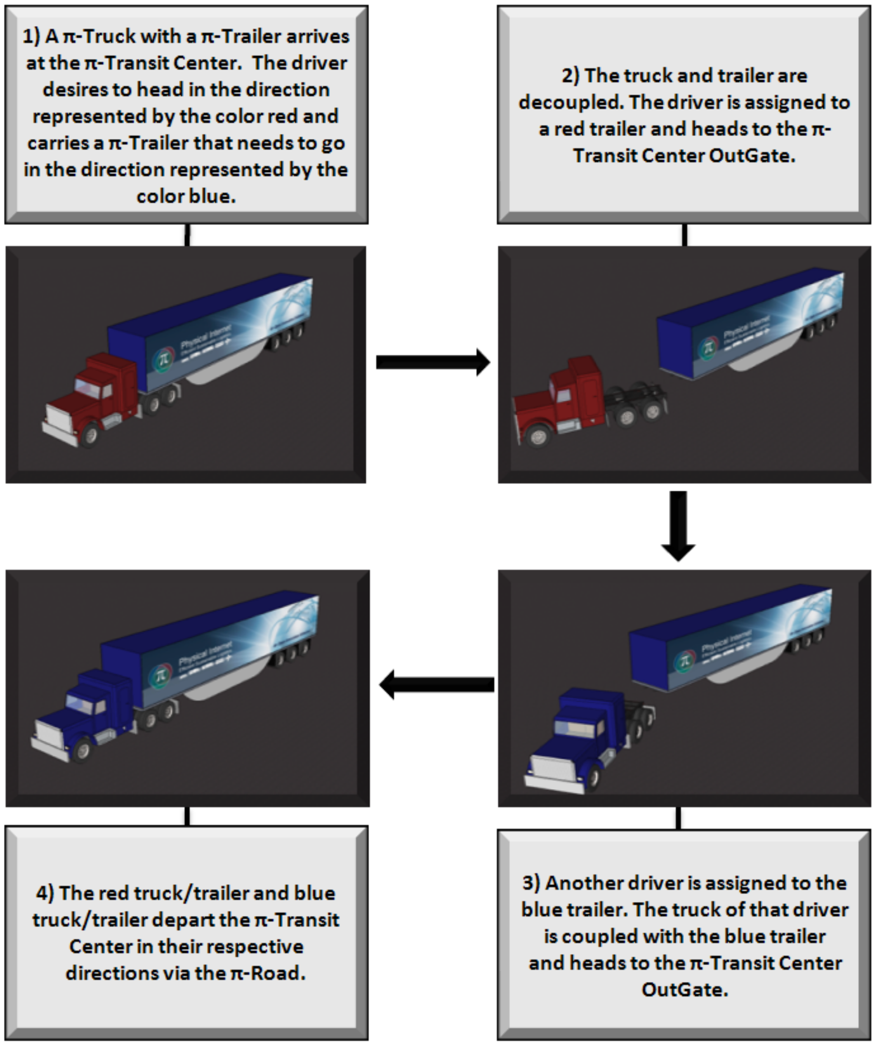

Figure 2: An Overview of the Flow of Trucks and Trailers in a PI Transit Center

2.1 Design Goals

The process at the π-transit that is described above will be subject to some degree of uncertainly with respect to exactly when driver-trailer pairs arrive at the π-transit. Thus, it is possible that the trailer, the driver, or both the trailer and driver will need to wait at the facility. The design of the π-transit, therefore, will need to accommodate such queueing time in accordance with the sustainability principles of the PI.

2.2 KPIs of Design

There are two sets of key performance indicators (KPIs) that we are interested. The first set of KPIs is from the perspective of "customers" of the π-transit and the second set is from the perspective of the operator of the π-transit. We will detail the two sets of KPIs below and then revisit this with our conceptual design at the end of Section 3.

2.2.1 From the Customer's Perspective

In simple terms, there are two customer perspectives to consider at a transit center. The first is the transportation service provider (represented by the truck/driver) and the second is the shipper (represented by the trailer).

For the truck/driver and the trailer, it is important to know what is the average time spent in the transit center, which is the sum of the time spent waiting at the gates, being processed at the gates, waiting to unhook, unhooking, waiting for a match to be made, hooking to a new trailer/truck, and then waiting to depart. We combine all of these times into the "switch time" (waiting to unhook, unhooking, waiting for a match to be made, hooking to a new trailer/truck) from the two perspectives (truck and trailer) and the "gate time" (waiting at the gates, being processed at the gates, and then waiting to depart). Of the two, the "switch time" is more variable and so, later, we will present an analytical model related to determining its value. Note that operational rules will likely play a role in the determination of the switch time. For example, do drivers accept an assignment to a trailer that is not going in the direction that they wish to depart? That is, if a driver arrives from the south and would like to return in that direction, at what point would the driver be willing to accept an assignment to the southeast or southwest? Therefore, a related KPI would be the percentage of time a driver is assigned to a trailer going in his/her preferred direction. And finally, how often is an expedited truck summoned to accept a trailer assignment?

Thus, although there are many other KPIs of interest to the customer, the main four are:

1. Average Throughput Time (Truck)
2. Average Throughput Time (Trailer)
3. Average Percentage Departing in Preferred Direction (Truck)
4. Average Percentage Expedited Assignments (Trailer)

2.2.2 From the Operator's Perspective

For the operator of the transit center, there is the typical tradeoff between capacity and costs. If the operator provides more switching bays, for example, then the average switch time will decrease (to a point; physical size would still work against some of the driving times in the transit center), but costs will increase. So, for now, we concentrate on KPIs related to the capacity of the transit center:

1. Area of Transit Center
2. Number of Gates (In)
3. Number of Gates (Out)
4. Number of Switch Bays
5. Number of Parking Bays (Trucks/Trailers)
6. Number of Parking Bays (Trucks)
7. Average Percentage Trucks/Trailers Declined Entrance (due to space issues in the transit center)

2.3 Contribution Towards Economic, Environmental and Social Sustainability

In this section we attempt to address how our conceptual design of a transit point contributes to economic, environmental and social sustainability. We believe that shared, collaborative transportation networks consisting of well-run transit centers allow for, on average: (1) trailers that are more full and (2) less empty miles between the end of one assignment and the beginning of the next assignment. We also believe that relay networks will emerge as the network topology, and with the volume of flow at a sufficient level, will permit the opportunity for drivers to be assigned to loads that are traveling less than a half-day's drive from their domicile location. This means that we can "get drivers home" more often without negative economic impacts.

Combined, the above will lead to fewer miles driven, which has significant positive economic and environmental impacts. And the networks themselves will lead to a higher quality of life for drivers. We also believe we are likely to see less trucks on the roads, which could have some positive impacts for society in terms of less congestion. As we are consciously trying through our design process to impact the environmental and social sustainability of the logistics system, evidence of this influence can be seen in the design of the facility.

3 Conceptual Design of Facility

The purpose of this section is to present a feasible conceptual design of a π-transit center. We are purposely **not** attempting to present an optimal design so that we can focus in great detail on the necessary elements of the design and not the design process. Our hope is that our design provides an example of what must be provided in terms of specifying a design and that others will follow as they determine better designs of a PI transit center.

3.1 Components of Facility's Design

In presenting our conceptual design of the facility, we will use many figures. And each figure will have up to five different types of flows represented on it. A color-coding is used, as illustrated in Figure 3.

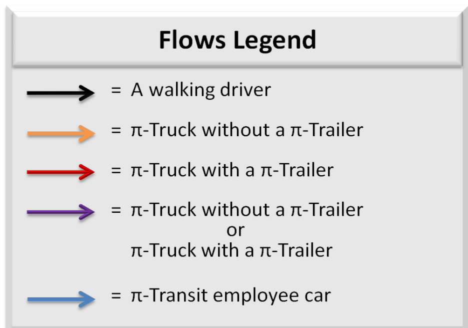

Figure 3: Legend of Flows in a PI Transit Center.

Note that at a high level, the PI transit center facilitates the flow of truck and trailer pairs from a π-road, facilitates the switch, and then facilitates the flow of new truck-trailer pairs back onto the road. Within the facility, the trucks can move independently. Thus, Figure 4 below represents the components of a π-transit center.

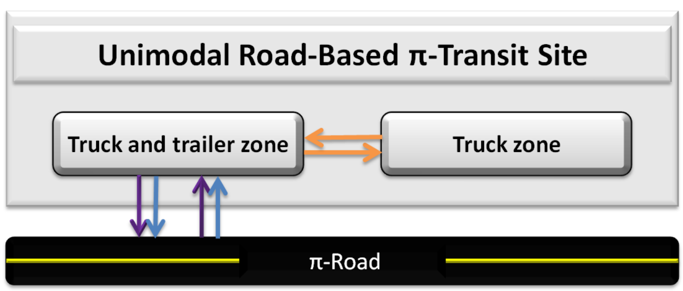

Figure 4: Illustration of Two Zones of a PI Transit Center.

To facilitate the mission of the π-transit center, the possible components we consider in a design are, as follows:

- Gates: In and out of the transit center (π-Gate In and π-Gate Out)
- Aisles: To permit movement from the various areas (π-Aisles).
- Manuevering areas: To permit the manuevering of truck/trailer pairs (π-Maneuver).
- Buffer areas: For the truck/trailer pairs and for trucks (π-Buffer and π-Parking).
- Switch area: To execute the swiching of trucks to new trailers and vice versa (π-Switch).

- Service area: To provide services to the drivers (restrooms, food/beverage, etc.; π-Service).

3.2 Illustrating the Functional Design of Facility

In the Figure 5 we present the flow diagram of our functional design of a π-transit center that combines the facility components referred to earlier. We also illustrate the major flows with the legend provided earlier in Figure 3.

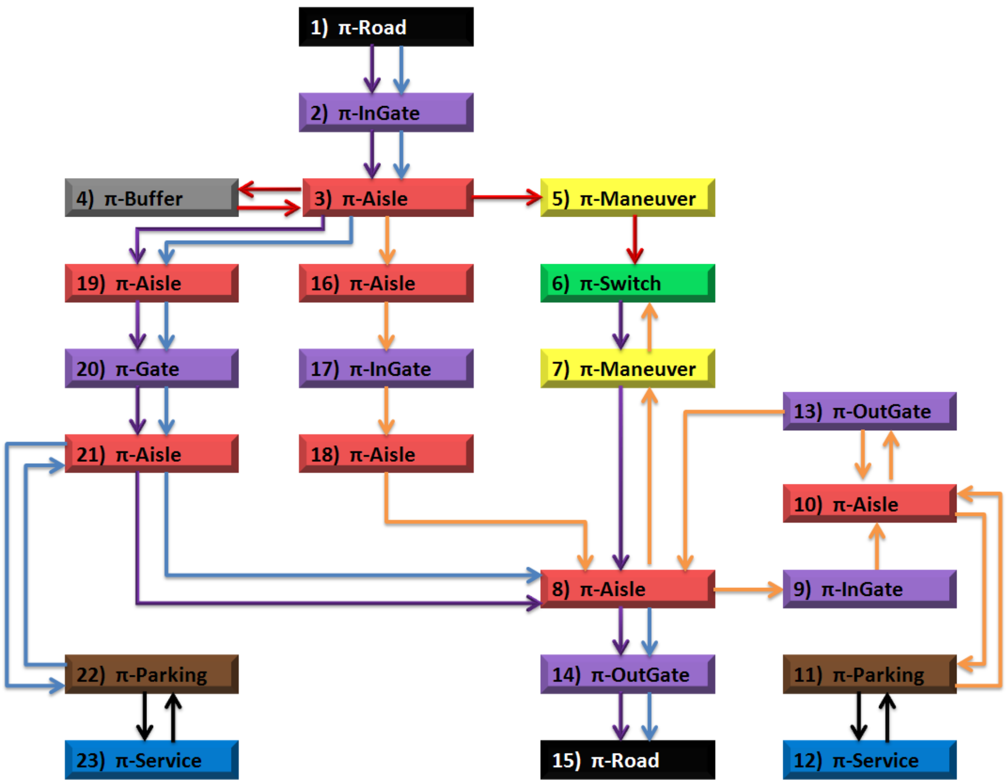

Figure 5: An Illustration of the Major Flows in a PI Transit Center.

Note that, in general, the goal of the truck-trailer pair upon entering through the PI-InGate is to make its way to the π-Switch. However, if there is no bay currently available in the π-Switch, we must provide a buffer for the pair to wait until a bay becomes available in the π-Switch. Likewise, after a truck drops its trailer, if the trailer to which it is assigned is not available, there is a buffer area provided in the Truck zone, which is where the driver services are also located. The flow then is to the π-OutGate. Throughout, π-Aisles are used to move between areas of the facility and the π-Maneuver is a special zone to accommodate the maneuvering of the trailer that requires more than a simple linear movement due to a practical limitation on aisle space.

In Figure 6 we present our functional design of a π-transit center that implements the flow diagram.

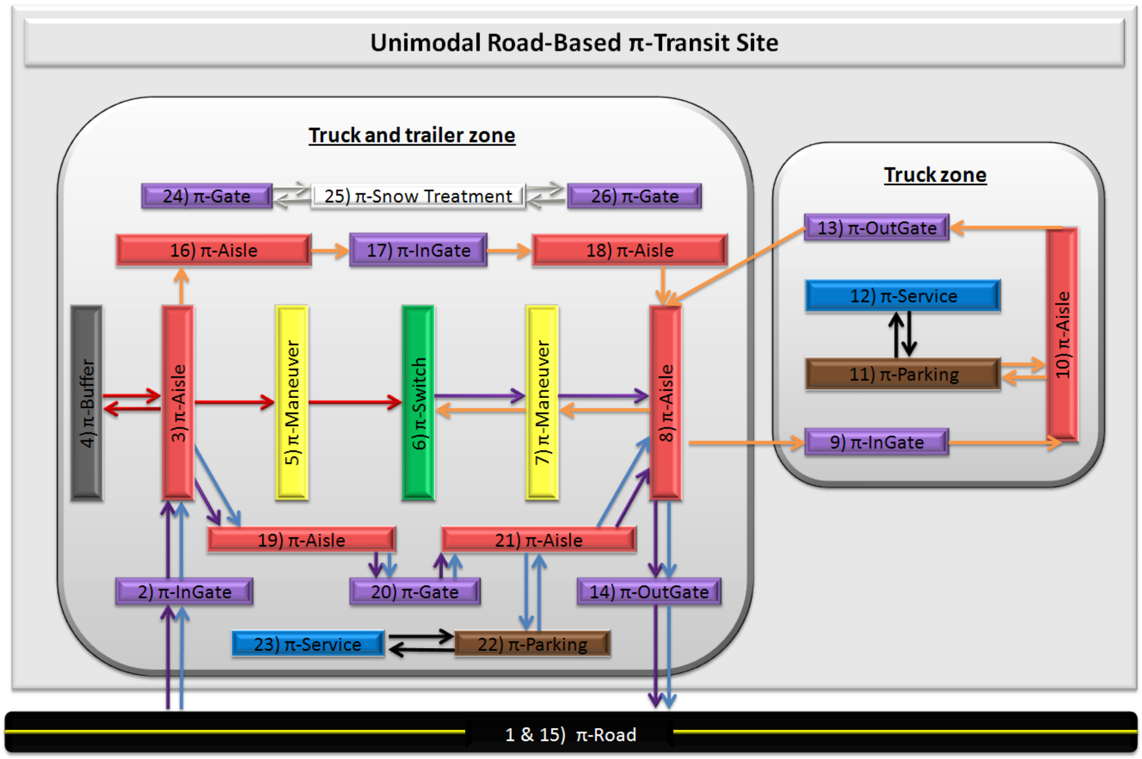

Figure 6: Proposed Functional Design with Switch Bays and Buffers.

Note that, in general, the flow of truck-trailer pairs is U-shaped within the facility (in gates on the left-hand-side and out gates on the right-hand-side) with the switch zone centrally located. The Truck zone is shown on the right-hand-side of the facility.

The next step in the functional design is to determine the area of each component to determine a relative block layout of the facility. In doing so we use a standard 53-foot trailer to specify the width and depth of facility components like the π-Gates, π-Aisles, π-Maneuver, and each bay of the π-Buffer, π-Parking, and π-Switch. The block layout is shown below in Figure 7.

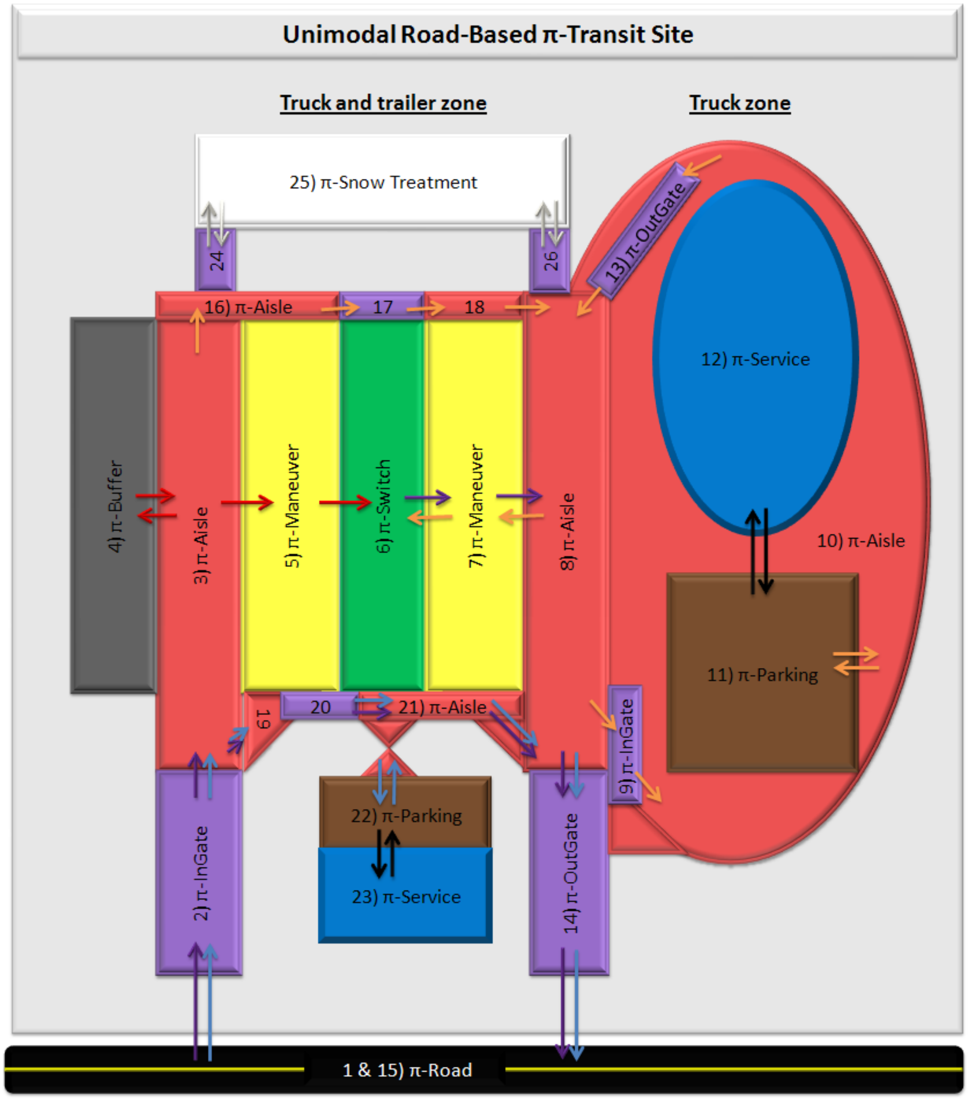

Figure 7: Block Layout for the Proposed Functional Design.

To ensure the completeness of our description of the functional design, we present a very detailed overview of the design in the Appendix.

3.3 Design Process

To go from a relative block layout to the final block layout, we need to use a capacity analysis of some sort to determine the relative number of, say, π-gates and π-switch bays. For this initial conceptual design, we used an iterative design process where we first sized the gates, then we sized the switch zones, and then we sized various buffers in order to determine a final design that could be simulated for its performance. Throughout, we used simple ratios based on average times to approximately size the design elements (e.g., if trucks/trailers take 10 minutes on average at a gate, we would assume we would need one gate per four or five arrivals per hour). We then used output from the simulation model (average queue sizes, average waiting times, etc.) to add or delete capacity from the design elements. Such a methodology was appropriate to determine a feasible design for this paper.

A more sophisticated design process would be to use analytical queueing models to determine the initial sizes. Such models would be an improvement over the design ratios because the relationship between flow and capacity is non-linear, which can be captured in queueing models, but which is difficult to capture in simple relationships.

For example, take the sizing of the switch zone, the most critical element of the PI transit center. The purpose of a model would be to produce an initial rough-cut estimate on the size of two areas in a PI transit point, the Truck Waiting Area and the Switch Zone. We argue that by sizing according to our model, the PI transit point operator could quote to potential customers KPIs related to the time a truck or trailer would spend in the transit point and be accurate within an operator-specified level of confidence. The initial model assumes independence between the sizing of the two areas, which leads to an upper bound on the sizes of the two areas and the KPIs.

3.3.1 Model Assumptions

We make a few simplifying assumptions:

1. The truck and trailer arrival process is Poisson with a mean of λ units per minute.
2. Trucks and trailers arrive with equal probability from a fixed number of directions, d.
3. A truck will depart in the same direction from which it arrived, waiting in a Truck Waiting Area until a trailer arrives that needs to depart to the direction the truck will depart.
4. A trailer will depart in one of the directions it did not arrive from, waiting in the Switch Zone until a truck is available to take it in its intended direction.
5. On average, trailers are equally satisfied to depart in one of d_t directions, where $1 \leq d_t \leq d - 1$.
6. The time to position the trailer and unhook the truck from it upon arrival in the Switch Zone is constant, t_u.
7. The time for the truck to hook to the trailer and certify connection before departure from the Switch Zone is constant, t_h.
8. All spots in the Truck Waiting Area and the Switch Zone are equivalent.
9. No delays at the gates or driving times are considered in the model.

As mentioned previously, two KPIs would likely be quoted to potential customers of the PI transit point:

1. The time between a truck arriving to the Switch Zone and departing from the Switch Zone will be less than T_c minutes.

2. The time between a trailer arriving to the Switch Zone and departing the Switch Zone will be less than T_t minutes.

Note, for model integrity, $T_c,\ T_t > t_u + t_h$.

Our model will be derived such that the two KPIs, KPI(1) and KPI(2), could be quoted with confidence levels, P_c and P_t, respectively. These two KPIs can be calculated after the size of the Truck Waiting Area and the size of the Switch Zone are determined.

3.3.2 Model

The objective of our model is to determine the size of the two areas, Truck Waiting Area and Switch Zone, to facilitate the match of a truck to a trailer. As the discussion below will make more clear, these are not independent decisions. However, as this is an initial model, we will make assumptions that will make the problem easier to solve, which will result in upper bounds on the sizing of these two areas, and thus, the values of the KPIs.

Let us begin by considering the trucks. Trucks arrive to the Switch Zone and drop their current trailer. In reality, there would be the possibility of being matched with one of the trailers already in the Switch Zone. However, to consider this possibility in our model would require sizing the two areas simultaneously. Therefore, we assume there is no available match and the truck must wait in the Truck Waiting Area until the *first trailer that arrives to the Switch Zone after the truck departs the Switch Zone* needs to go in the direction the truck wishes to travel.

For each subsequent arrival to the Switch Zone, there is a probability of $1/d$ the trailer can be matched to the waiting truck. Thus, using Bernoulli trials, we can determine the probability until the first match occurs. As we have a threshold probability value, we will use it to determine the number of trials. That is, how many trials, n_c, must occur such that there is a better than P_c chance of having at least one match. Of course, this is equal to one minus the probability of no matches within n_c trials, which is equal to $1-(1-P_c)^{n_c}$. Thus, we denote n_{c^*} as the minimum integer such that $1-(1-1/d)^{n_{c^*}} \geq P_c$.

Thus, KPI(1), the time such a trailer would spend from arriving at the Switch Zone and departing the Switch Zone, would equal $t_u + n_{c^*}\lambda + t_h$ and would require a Truck Waiting Area of no more than size n_{c^*}.

An analogous argument and derivation exists for the trailers. We summarize by saying that the transit point would require a Switch Zone of no more size than n_{t^*}, such that n_{t^*} is the minimum integer satisfying $1-(1-d_t/d)^{n_{t^*}} \geq P_t$. Then, KPI(2) would equal $t_u + n_{t^*}\lambda + t_h$.

3.3.3 Example

We illustrate the above model with an example using the following data:

- Trucks and trailers arrive at a rate of 2/minute from one of 8 directions ($\lambda = 2; d = 8$).

- Trucks wish to return in the same direction from which they came and trailers, on average, can depart in one of 2 directions ($d_t = 2$).
- The time to position and unhook a trailer is equal to the time to hook and certify connection, 5 minutes ($t_u, t_h = 5$).
- Threshold probabilities are both equal to 0.99 ($P_c, P_t = 0.99$).

For the trucks, there is a 1/8 chance any arriving trailer will wish to go in the direction it wishes to travel. To find at least one match in a set of trials (where the chance of success of any one trial equals 1/8) with a probability of at least 0.99 requires 35 trials. Thus, the truck will be in the Truck Waiting Area (of size 35) for no longer than 17.5 minutes and thus, KPI(1) equals 27.5 (5 + 17.5 + 5) minutes.

For the trailers, there is a 2/8 chance any arriving truck will wish to go in one of the two directions it wishes to travel. To find at least one match in a set of trials (where the chance of success of any one trial equals 2/8) with a probability of at least 0.99 requires 17 trials. Thus, the Switch Zone will need to have no more than 37 spots (17 for waiting and 20 for hooking and unhooking during the 10 minutes of processing). Also, the trailer will spend no more than 18.5 (5 + 8.5 + 5) minutes in the Switch Zone; i.e., KPI(2) equals 18.5 minutes.

3.4 Final Layout

For this section, we used the following data when determining out final layout:

- Arrival rate, which varies by the hour of the day and the day in the week:
  - 4,000 trailers/week
  - Min: 0.6 trailers/hour
  - Average: 23.73 trailers/hour
  - Max: 62.25 trailers/hour
  - From 4 directions with equal probability
  - Trucks want to return in the direction of arrival (but accept another after 30 minutes)
  - Trailers will be expedited after 120 minutes if a truck has not accepted their assignment.
- Split process: Time to unhook the carrier from the truck
  - Pert(1; 2.5; 5 minutes)
- InGate processing time:
  - Normal Security: Exponential(0.5 minutes)
  - High Security: Exponential(1 minute)
- Switch processing time:
  - Pert(3; 7; 15 minutes)
- OutGate Processing Time:
  - Normal Security: Exponential(0.5 minutes)
  - High Security: Exponential(1 minute)

Using the design process discussed earlier, we sized the facility's capacity as follows:

- Number of InGates: 4 (2 normal security and 2 high security)
- Number of Buffer Spots for Truck-Trailers: 24
- Number of Switch Zone Spots: 24
- Number of Truck Parking Spots: 24
- Number of OutGates: 4 (2 normal security and 2 high security)

We will now present our final layout from multiple perspectives. First is an overhead view of our final π-transit center layout in Figure 8.

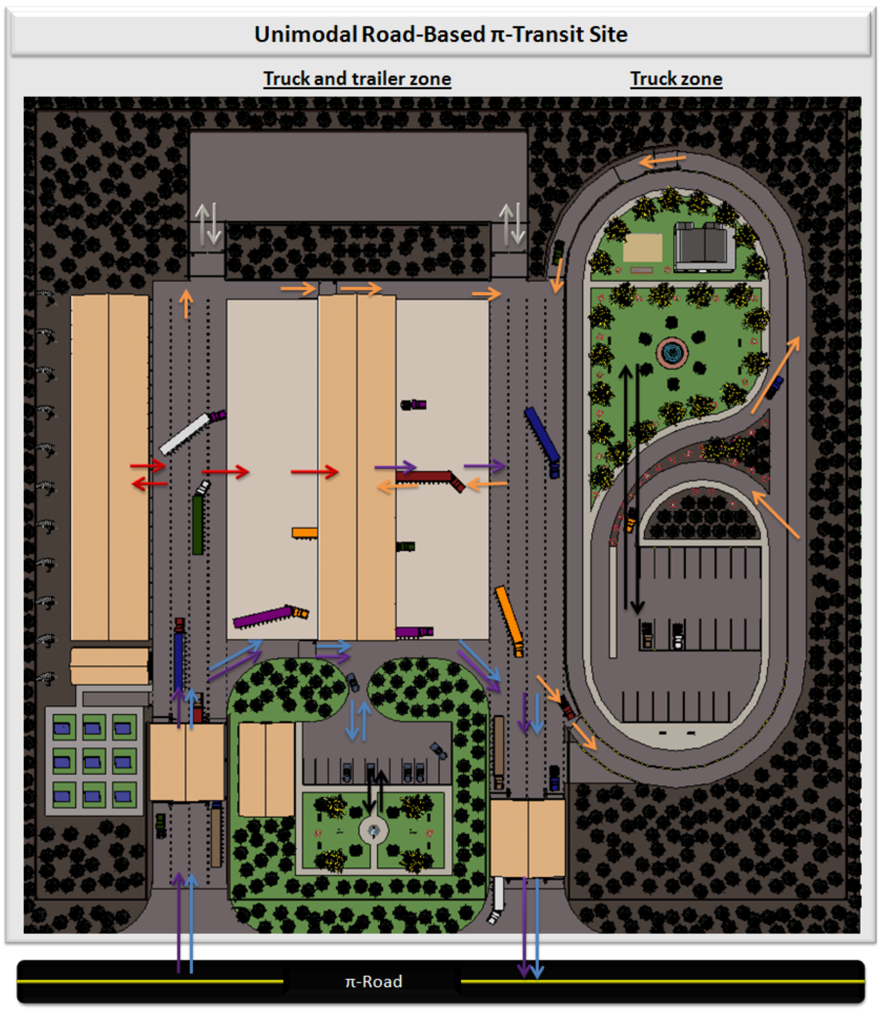

Figure 8: Final Layout of Proposed Design (Overhead View).

Next a 3D-view in Figure 9 that gives a sense of the facility from the front. Note the solar panel field on the left-hand-side of the site for environmental and energy production considerations.

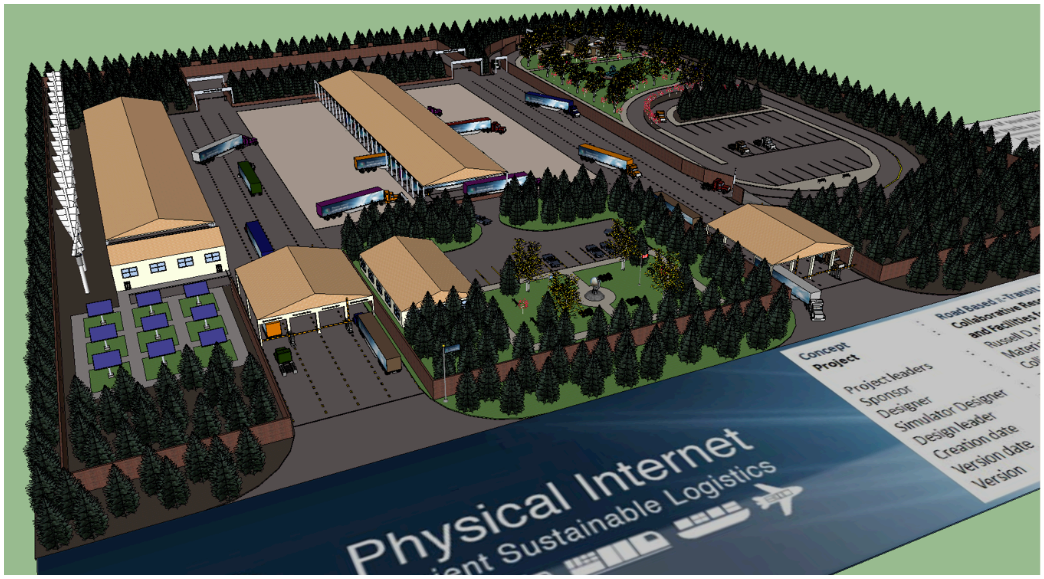

Figure 9: Final Layout of Proposed Design (Front View).

Next a 3D-view from the side in Figure 10, which not only illustrates the switch bays better, but also the wind turbines, which combined with the solar panel field, provide the energy requirements to the π-transit center.

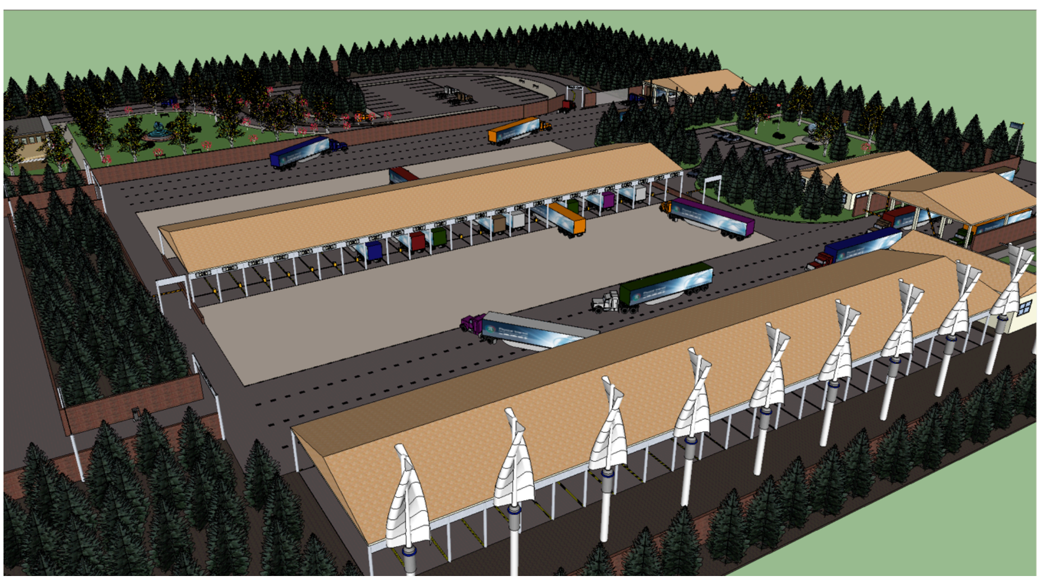

Figure 10: Final Layout of Proposed Design (Side View).

The final 3D-view in Figure 11 provides illustrates the truck and driver service area, which includes such amenities as restrooms, a small park (complete with fountain!).

Figure 11: Final Layout of Proposed Design (Driver Service Area).

3.5 KPIs of the Facility

Although the focus of this paper is not on how to determine the values of the KPIs, providing them for this conceptual design allows the reader to get a sense for how well the facility is operating. The KPI values were determined via a detailed discrete-event simulation (coded in Simio [4]).

KPI	**Value**
Customer	
Average Throughput Time (Truck)	30.73 minutes
Average Throughput Time (Trailer)	32.76 minutes
Average Percentage Departing in Preferred Direction (Truck)	79.84%
Average Percentage Expedited Assignments	0.84%
Operator	
Area of Transit Center	50,625 m^2 (544,923 ft^2)
Number of Gates (In)	4
Number of Gates (Out)	4
Number of Switch Bays	24
Number of Parking Bays (Trucks/Trailers)	24
Number of Parking Bays (Trucks)	24
Average Percentage of Declined Trucks/Trailers	1.23%

In order to show that the functional design can have an impact on the KPIs, we present an alternative design (in less detail). Consider a design where there are more switch bays and no parking bays for Truck/Trailers (we still provide parking bays for trucks, as this area also serves the purpose of facilitating the delivery of services for drivers). We wondered about the performance of such a design. And because switch bays would be more expensive than the parking bays we converted half of the parking bays to switch bays (that is, from 24 parking bays and 24 switch bays to 0 parking bays and 36 switch bays). This alternative functional design is presented in Figure 12. Note that for this design without parking bays for Truck/Trailers, the switch bays are arranged in two columns. Thus, for traffic flow issues and ease of expansion the driver service area is located at the top.

The KPIs for the alternative design are shown below.

KPI	**Value**
Customer	
Average Throughput Time (Truck)	29.48 minutes
Average Throughput Time (Trailer)	30.79 minutes
Average Percentage Departing in Preferred Direction (Truck)	87.03%
Average Percentage Expedited Assignments	0.47%
Operator	
Area of Transit Center	63,840 m^2 (687,168 ft^2)
Number of Gates (In)	4
Number of Gates (Out)	4
Number of Switch Bays	36
Number of Parking Bays (Trucks/Trailers)	0
Number of Parking Bays (Trucks)	24
Average Percentage of Declined Trucks/Trailers	0.54%

As can be seen from comparing the KPI values, the two functional designs result in a tradeoff. The alternative design appears to have slightly better performance with respect to customer KPIs, but at an increase in area. Thus, we concluded that this design may work better for a higher throughput scenario. Thus, we increased the demand placed on the transit center from 4,000 to 6,000 trailers per week, which required an increase in the number of switch bays in the alternative design to 48 (which results in an overall area of 72,000 m^2, or 775,002 ft^2) to maintain similar customer KPIs.

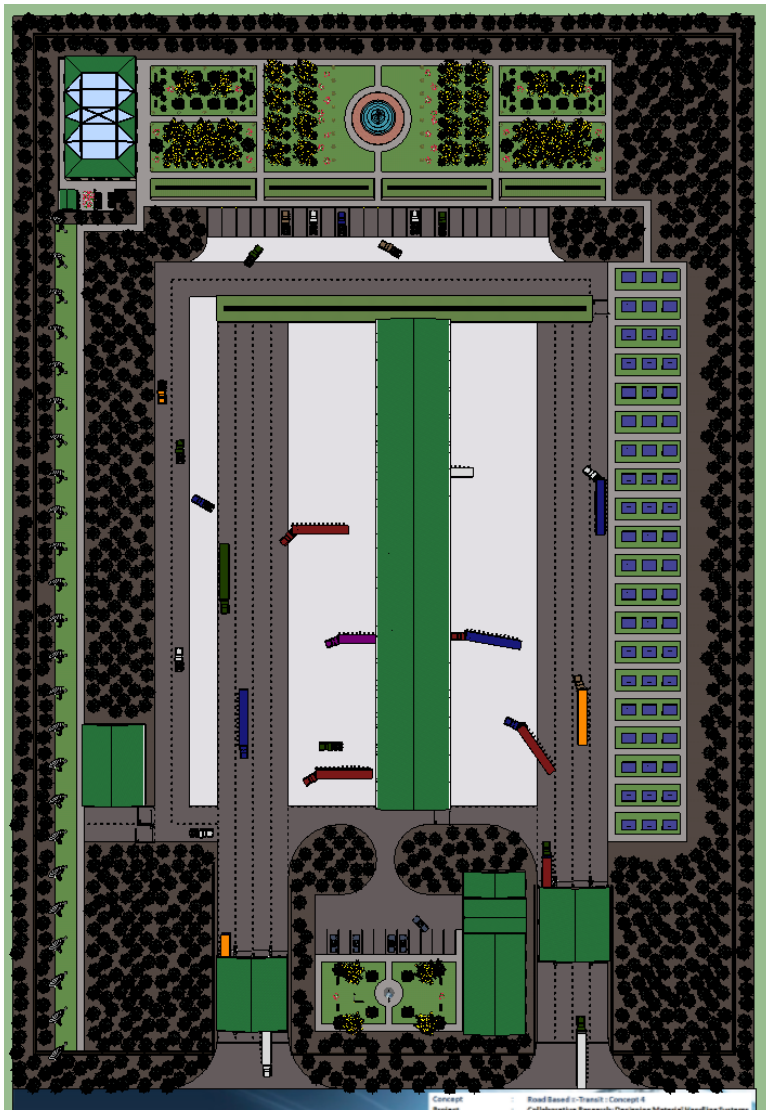

Figure 12: Alternative Design of a PI Transit Center.

4 Conclusions and Future Research

As stated at the outset, the goal of this chapter was not to produce the optimal functional design of a PI transit center. Rather, our primary goal was to produce a functional design that performed at an acceptable level in terms of user key performance indicators (KPIs). We also reported KPIs that a facility operator is likely to consider. Our secondary goal was to establish what details are needed to provide when one provides a functional design going forward.

Examination of our work will hopefully lead to future research on two fronts. First, we hope that functional designs of π-transit centers that differ from the two that we presented here will be developed. As it is unlikely that one functional design will perform best over all possible ranges of input parameters, having a suite of functional designs to choose from will aid future facility operators.

Second, we used simulation as a means to evaluate our designs because we believe this is the most appropriate method for establishing the performance of the facility. However, simulation is a cumbersome process when also used, as we did, to iteratively design a facility and sequentially choose the appropriate levels of resources. We presented a possible model for the π-switch zone, but other analytical queueing models would be helpful in terms of evaluating the performance of sub-systems of the facility.

Third is the design process itself. We used a linear, sequential design process to allocate resources initially, and then used simulation of the total system in an attempt to fine-tune those resource allocations. More complex design processes may not only reduce and streamline the design realization efforts, but also improve the designs that result.

Acknowledgements

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Appendix

The block layout presented earlier in this chapter is used to support a detailed description of the functional requirements of the facility. Please refer back to Figure 7.

Figure 13: π-InGate.

1. A truck with or without trailer leaves the π-Road and enters the π-Transit (Figure 13). The trucks can have different origins or destinations. For example, trucks can come from another π-Transit, trucker's home, a local pick up, or other π-Facility and go to different types of π-Facilities. Trucks have to be recorded in a Timetable that is managed by the π-System of the Physical Internet. Indeed, the π-Transit works by booking some π-Switch bays to adequately fill them in a precise time frame. Every movement made by vehicles have to be managed and controlled to ensure a level of performance and efficiency of the π-Facility. In short, every truck that has to enter the π-Transit has to make a request to the π-System. This system analyses the request and provides the access code prior to

passing the π-InGate (node 2) and reserves a bay in the π-Switch of the π-Transit for a truck and a trailer, when pertinent. Also, the π-System can follow the movement in real time and knows the exact location and state of all trucks, trailers, equipment and π-Facilities of the Physical Internet supplying network.

2. A truck with or without trailer comes from the π-Road (node 1) and rides under one of the four security gates of the π-InGate. Depending on the request of the π-System or on the transportation needs, the truck with or without trailer goes under a rapid or deep security scan. If the entity is going through the deep scan, all its equipment is for example inspected by an X-ray and a radiation detection system to identify illegal merchandises or dangerous goods. This inspection is automatic and is done with both the π-System and a security agent of the management office. A special procedure is engaged if something is considered unusual. The rapid security gates circumvent this procedure for vehicles and trailers, but both kinds of security gates will read or update information on the driver identification smart card and the trailer smart card. A precise description of the equipment and smart card system will be further developed in another section of this report. The information taken from the vehicles is compared with those of the π-System database. If everything matches, the π-System will transfer a work order to the truck's multidisciplinary dashboard computer. If something is wrong, a special procedure is starting. At the same time, all the authorizations needed to move into the π-Transit are sent to this computer. The work order is assigned depending on contingencies, needs and capacities of the π-Transit. Each work order is obtained by different algorithms from the π-System in order to reduce traffic and time wasted. This work order shows every π-Aisle that can be taken and every location that can be reached so the job can be correctly completed inside the π-Transit, in a specific time frame. When the driver has manually confirmed that he has received and understood the work order and all the authorizations he needs for the π-Transit, a barrier rises and lets him enter through the π-Aisle (node 3; Figure 14) in front of him.

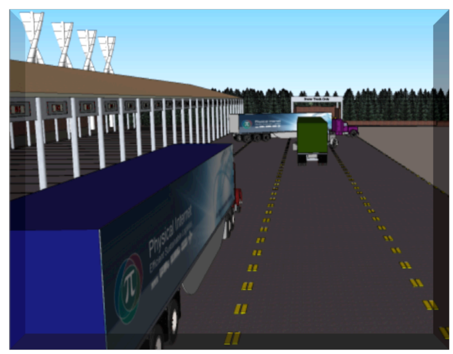

Figure 14: π-Aisle.

3. A truck, with or without trailer, is riding on a four-way π-Aisle (node 3) in order to allow the driver to reach all the destination marks on his work order, formerly given by the π-System. Trucks with trailer have received one of these two orders, before heading into the temporary π-Buffer (node 4) or heading into the π-Maneuver (node 5). On the other hand, the trucks without trailer have to go to the π-Aisle (node 16). So, three scenarios are possible in this zone.
   a. When at least one π-Switch bay is free, the trucks with trailers head straight to the π-Maneuver to access the entrance of the π-Switch bay indicated in the work order. In this case, the π-Switch bay is empty and ready to receive a new trailer.

b. When the π-Switch is entirely full, the π-System will give a temporary place to a truck hauling a trailer to wait until the π-Switch releases a space. Then, the trucker will move back from the π-Aisle to go on the π-Buffer (node 3) in accordance with his work order. While the trucker backward in his appropriate waiting bay, a smart card reader collects the truck and trailer information in order to compare them with the π-System database. This action will update the database and therefore avoid some subsequent managerial errors. Beforehand, the π-System has attributed the waiting bay closest to from the assigned π-Switch bay.

c. A truck without trailer reaches the π-Aisle (node 16). The worker has been called to take charge and transport a trailer that is waiting for a carrier in a π-Switch bay. This event can happen if there is no carrier needing to go in the same direction of the trailer, in a reasonable specific delay of the π-Facility. In this case, the π-System consults its database in order to find possible concordance between the transportation needs of the trailer and a carrier transportation that fits with the needs. When there is a match, the π-System sends a work order to the trucker via the truck's multidisciplinary dashboard computer and updates its database. If there is nobody available to carry the trailer in the Physical Internet supplying network, an employee of the π-Transit will take possession of this trailer and will transfer it from the π-Switch to a temporary stocking bay in the π-Buffer Zone, it is intended for this situation to be rare.

4. The π-Buffer (Figure 15) homes trucks with trailer that come from the π-Aisle (node 3), for a normally short period. The trucks with trailer patiently wait in this area until their dedicated π-Switch bay is about to be released. At this moment, the π-System orders the trucker, via his truck's multidisciplinary dashboard computer, to move in the π-Aisle (node 3) in order to reach the π-Maneuver (node 5). Then, the truck with trailer reaches the π-Switch bay and can leave is trailer there.

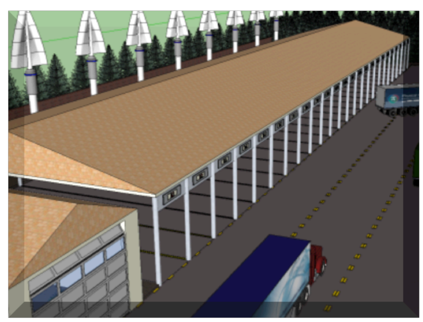

Figure 15: π-Buffer.

5. Inside the π-Maneuver (Figure 16), the driver leading the truck with trailer makes moves and turns in order to get forward correctly in the π-Switch bay in accordance with his work order transmitted by the π-System. This free-movement area is essential to get straight inside a specific π-Switch bay (node 6). In this zone, trucks with trailers will all come from the π-Aisle (node 3) and will leave a trailer in a π-Switch bay.

Figure16: π-Maneuver.

6. Two scenarios may occur in the π -Switch (node 6; Figure 17), a truck leaves a trailer in a π-Switch bay or a truck without a trailer hooks a trailer in a π-Switch bay. The only way to reach a π-Switch bay is by passing through the π-Maneuver (node 5 or 7).

Figure 17: π-Switch.

   a. In the first situation, a truck with trailer has come from the π-Maneuver (node 5) and moves forward in a dedicated π-Switch bay. While the carrier slowly progresses inside the π-Switch bay, a smart card reader collects the driver and trailer information in order to compare it with the π-System database and the dedicated driver work order. When there is unconformity between the database and the information encapsulated in the smart cards, an error message is shown on the truck's multidisciplinary dashboard computer to inform the driver that he is not in the right π-Switch bay. In this situation, the driver has to leave the π-Switch bay to go back into the π-Maneuver (node 5) and find the appropriate π-Switch bay. Otherwise, if everything is congruent, the truck with trailer moves inside the π-Switch bay by following the instruction of a light system and his truck's multidisciplinary dashboard computer.

      While he is moving inside the bay, a yellow light indicates the driver to move slowly forward until the red light is flashing, which means he is really close to his destination. When the yellow light disappears and when the red light turns on completely, the driver has to stop because he is entirely inside and exactly at the right place in the π-Switch bay. Then a black light starts flashing, which means the trailer wheel locking system is deployed in order to safely transfer the legal obligation of the trailer to the π-Transit. Also, the wheel locking system allows the π-System to have better control on the flow management, increase the security level and decrease the number of human errors inside the π-Transit. When the wheels are completely blocked, a steady black light appears to indicate to the driver that he can get out of his truck to disconnect the trailer from the truck. Then, the driver can go back in his truck and press a confirmation button in the truck's multidisciplinary dashboard computer to indicate that he is ready to go. The π-System analyses the request and turns the light to green when the driver is authorized to move slowly towards the π-Aisle (node 7). The π-System updates its database when the truck is out of the π-Switch bay.

   b. In the second situation, a truck without trailer comes from the π-Maneuver (node 7) and moves backward in a dedicated π-Switch bay. While the carrier slowly progresses inside the π-Switch bay, a smart card reader collects the driver and trailer information in order to compare them with the π-System database and the dedicated driver work order. When there is an unconformity between the database and the information encapsulated in the smart cards, an error message is shown on the truck's multidisciplinary dashboard computer to inform the driver that he is not at the right π-Switch bay. When this occurs, the driver has to leave the π-Switch bay to go back into the π-Maneuver (node 5) and find the appropriate π-Switch bay. Furthermore, if it is not similar, the wheel locking system will still be activated and will not let the truck leave with the trailer by keeping is wheels blocked. At this moment, the black light that is used to show that the trailer wheels are blocked by a locking system is on. This property enhances the security level of the π-Facility and reduces the probability for mistakes. Otherwise, if everything is congruent, the wheel locking system is disabled and retracted to let the driver fix the trailer to his vehicle. When this procedure occurs, the black light turn into a flashing one until it turns off completely. When this is done, the designated person takes possession of the legal obligations related to carry the trailer from the π-Transit to one specific destination in the supply network.

So, the truck without trailer moves inside the π-Switch bay by following the instruction of the light system and the truck's multidisciplinary dashboard computer. A yellow light indicates to the driver to move slowly backward until a red light is flashing, which means the driver has to move carefully because he is near of the trailer hitch. When the vehicle reaches the hitch, the yellow light turns off and the red light completely on, the driver temporarily stops his truck and completes the junction between the truck and the trailer. After that, the driver, as a safety measure, starts a routine inspection of his vehicle and his new trailer to look for any damage or malfunctions. Then, the driver can go back in his truck and press a confirmation button in the truck's multidisciplinary dashboard computer to indicate that he is ready to go. By pressing the button, he communicates with the π-System that the wheel locking system is disabled and that the inspection of the vehicles is completed, the π-System turns the green light on. The π-System analyses the request and turn the light to green when the new pair of truck and trailer are authorized to move slowly in the π-Aisle (node 7). The π-System updates his database when the truck is out of the π-Switch bay.

7. Five scenarios are possible for a truck with or without trailer coming from different zone of the π-Transit inside the π-Maneuver (node 8; Figure 18). The π-Maneuver is a free-movement zone and allows the user to do different moves in order to execute the work order given by the π-System.

Figure 18: π-Maneuver.

   a. A truck with trailer has left the π-Switch and moves in the π-Maneuver (node 7). At this point, the truck with trailer has no choice than to go to the π-OutGates (node 14) by the π-Aisle (node 8).

b. A truck has left a trailer in a π-Switch bay and is in the π-Maneuver (node 7) to take another trailer in a different π-Switch bay. The truck exits one π-Switch bay, moves around and backs into another π-Switch bay to take possession of a trailer in accordance with his work order. This is a really efficient procedure that is intended to occur often.
c. A truck has left a trailer in a π-Switch bay and moves in the π-Maneuver (node 7). The truck wants to reach the π-OutGate (node 14), by the π-Aisle (node 8), because he has finished his workday or the π-System did not assigned another task for him.
d. A truck has left a trailer in a π-Switch bay and moves in the π-Maneuver (node 7). The truck wants to reach the π-Parking (node 11) through some node (indeed node 8, 9 or 10) because the π-System has allocated another task to him or the driver simply wants to go to the π-Service to spend some time. If the π-Parking is full, the π-System will not allow him to pass a moment there.
e. A truck without trailer came from the π-Aisle (node 8) and moves on the π-Maneuver (node 7) in order to pick-up a trailer in the right π-Switch bay, in accordance with his work order.

8. A truck with or without trailer is moving on a four-way π-Aisle (node 8; Figure 18) in order to allow the driver to circulate to the destination according to the work order formerly provided by the π-System. The vehicles may come from different origins and eight plausible scenarios can occur in this zone.

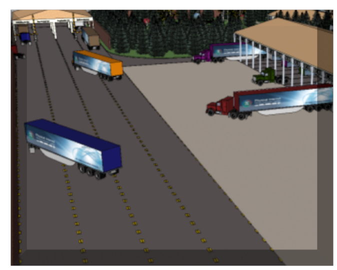
Figure 19: π-Aisle.

a. A truck without trailer comes from the π-Aisle (node 19) or from the π-OutGate (node 13) and moves in the π-Aisle (node 8) to reach the π-Switch. The truck has to go in a π-Switch bay to take possession of the trailer in accordance with the work order. Then, the truck has to pass by the π-Maneuver (node 7) to reach a trailer in a π-Switch bay (node 6).
b. A truck has left a trailer in a π-Switch bay according to his work order and came from the π-Maneuver (node 7). The truck is moving in the π-Aisle (node 8) and wants to go in the restricted truck without trailer area of the π-Transit. To reach this place, the truck has to pass by nodes number 9 and 10 in order to go in the π-Parking or the π-Service.
c. A truck without trailer comes from the π-Aisle (node 18) and moves in the π-Aisle (node 8) in order to reach the π-Parking or the π-Service by nodes number 9 and 10.
d. A truck without trailer comes from the π-OutGate (node 13) and moves in the π-Aisle (node 8) to reach the π-OutGate (node 14) to get out of the π-Transit. The driver has just passed moments of pleasure and relaxation in the π-Service and has finished his workday or his work order in the π-Transit.
e. A truck has left a trailer in the π-Switch and comes from the π-Maneuver (node 7) and moves in the π-Aisle (node 8) in order to reach the π-OutGate (node 14)

in order to get out of the π-Transit. The driver has finished his workday or his work order in this π-Transit.

f. A truck has taken possession of a new trailer from a π-Switch bay in accordance with his work order and has come from the π-Maneuver (node 7). The truck moves in the π-Aisle (node 8) in order to reach the π-OutGate (node 14) to get out of the π-Transit. The driver has to correctly complete his work order given by the π-System and goes to another π-Facility.
g. A truck with or without a trailer entered the π-Transit by mistake and has to go out. The carrier comes from the π-Aisle (node 21) and moves in the π-Aisle (node 8) to reach the π-OutGate (node 14) in order to get out of the π-Transit.
h. An employee of the π-Transit gets out of the transit because he finished her/his workday or wants to have a lunch outside the π-Transit. The employee car comes from the π-Aisle (node 21) and moves in the π-Aisle (node 8) to reach the π-OutGate (node 14) in order to get out of the π-Transit.

9. The π-InGate (node 9; Figure 20) is only used to count the number of trucks that go in the truck-without-trailer restricted area and update the π-System database with the information. This information is used to adequately manage flows in the π-Transit. Trucks have to pass under a smart card reader that transfers the information to the π-System in order to change the database information. Trucks without trailers exclusively come from the π-Aisle (node 8) heading to reach π-Aisle (node 10).

Figure 20: π-InGate.

10. The loop π-Aisle (node 10; Figure 21) has been developed to allow several connections between neighbouring zones, to increase flow fluidity and to provide more displacement autonomy to this truck restricted area. Four scenarios can occur in this zone.

Figure 21: π-Aisle.

a. A truck without trailer arrives from the π-InGate (node 9) and moves on the π-Aisle (node 10) in order to reach the π-Parking. The driver is able to wait in the π-Parking or in the π-Service for a pre-planned period by the π-System and then he returns back in service.
b. The π-System has suddenly updated the work order of the driver and has planned a really short waiting time in the restricted truck area. This can happen if the π-System gives another work order to a trucker that did not have one before. The driver probably wanted to go in the π-Parking or the π-Service but a new circumstance changed the initial planning. The truck comes from the π-InGate (node 9) and moves in the π-Aisle (node 10) in way to reach the π-OutGate (node 13).

c. A truck without trailer arrives from the π-Parking (node 11; Figure 22) and moves in the π-Aisle (node 10) in order to reach the π-OutGate (node 13). This action enables the truck without trailer to exit the truck-restricted area and return in the trucks with trailer zone.

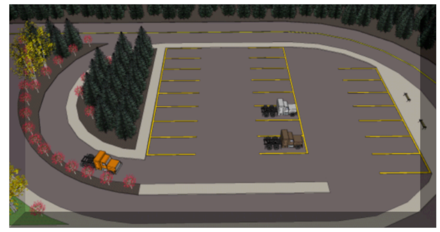

Figure 22: π-Parking.

d. A truck without trailer arrives from the π-OutGate (node 13) and moves in the π-Aisle (node 10), because the truck got to the π-OutGate too early or the π-System has suddenly changed the schedule and has redirected the driver inside the truck restricted area. The truck has not received the authorization to pass the π-OutGate at this time. The driver receives an update on his truck's multidisciplinary dashboard computer. This informs him of the modifications made by the π-System to his work order. Then, the truck without trailer moves to the π-Parking (node 11) or goes back in queue for the π-OutGate (node 13), in accordance with the updated work order.

11. A truck without trailer is parked in the π-Parking (node 12). While the truck stays in the π-Parking, the driver can take a break and wait inside his truck or go to the π-Service (node 12) until he receives the next planned task of his work order. Otherwise, the driver's workday is over and this allows him to stay and enjoy the services offered for a moment before he leaves the π-Transit. The only way to enter or exit the π-Parking is by the π-Aisle (node 10).

12. A driver has parked his truck without trailer in the π-Parking and he is free to walk in the π-Service (node 12; Figure 23) that provides different services to Physical Internet drivers. The π-Service is only accessible by the π-Parking (node 11) and this is the only place that allows truckers to walk freely. This resting and entertaining area is green and allows the drivers to stretch their legs, use washrooms and eat at restaurants. They have access to a nice small park strewed of trees, benches, picnic tables, green spaces and a fountain in the center. This area provides the social development aspect of the π-Transit and offers a really quiet environment due to his noise barriers.

Figure 23: π-Service.

13. A truck progresses in the π-OutGate (node 13; Figure 24) in order to exit the restricted truck-without-trailer area. The truck must come from the π-Aisle (node 10). A smart card reader collects information on the driver, the truck, consults the work order and transmits them to the π-System in order to approve or deny access to the π-Aisle (node 8). Information needed by the truck is already in its multidisciplinary dashboard computer

Figure 24: π-OutGate.

database, all the access codes it needs to go in various zones. Nonetheless, the variation of flow activities in the π-Transit can temporarily block some access to zones to ensure a level of security and efficiency. Two scenarios can occur:

a. The π-System allows the truck to access to the π-Aisle (node 8) because the flow levels in that π-Aisle and in the π-Maneuver (node 7) are under the allowed threshold. Also, there could be another constraint that needs to be respected for the barrier to rise. If the trucker has to take possession of a new trailer in accordance with the work order, the trailer has to be ready for a pick up in the π-Switch bay. If the trucker's workday is over, only the level-of-flow constraint has to be respected.
b. The π-System does not allow the trucks to access to the π-Aisle (node 8) because the flow levels in that π-Aisle and in the π-Maneuver (node 7) are over the threshold allowed. Also, the π-System can reject the access to the next zone if the trucker has to take possession of a new road based trailer in accordance with his work order and it is not already in position in the π-Switch bay. Then, if one of the requirements is not satisfied, another barrier rises and returns the truck to where it came from, in the π-Aisle (node 10).

14. A truck with or without trailer comes from the π-Aisle (node 8) and rides under one of the four security gates of the π-OutGate (Figure 25). Depending on the request of the π-System or the transportation needs, the truck with or without trailer goes under a rapid or deep security scan. If the entity is going through the deep scan, all its equipment is for example inspected by an X-ray and a radiation detection system to recognize illegal merchandise or dangerous products. This inspection is automatic and done jointly with the π-System and a security agent. A special procedure is engaged if something illegal or unusual is found. The rapid security gates avoid this procedure to vehicles and trailers, but both kinds of security gates will read and updated information on the driver identification smart card and the road based trailer smart card. After that, the information taken from the vehicles are used to update the π-System schedule and historic databases. Simultaneously, a barrier rises and allows the truck with or without a road based trailer to exit the π-Transit and go back to the π-Road (node 15).

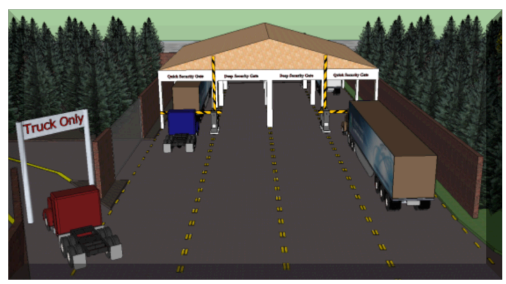

Figure 25: π-OutGate.

15. A truck with or without a road-based trailer has just exited the π-Transit by the π-OutGate (node 14) to reach the π-Road. Three scenarios can occur:
    a. A truck with or without a road based trailer is trying to complete his work order or the driver has just finished his workday and his no longer available to work in the Physical Internet supply chain today.
    b. A truck with or without a trailer entered the π-Transit by mistake and will depart to reach the road.

c. An employee of the π-Transit gets out of the transit by car because he finished is workday or wants to go outside the π-Transit and come back afterwards.

16. A truck without trailer is moving in the π-Aisle (node 16; Figure 26) to have a quick easy access to the π-Aisle (node 8). This truck came from the π-Aisle (node 3) because the driver received a carrier affectation by the π-System. To reach the π-Aisle (node 8), the truck has to pass an authorization π-Gate (node 17).

Figure 26: π-Aisle.

17. A truck without trailer is situated at the π-Gate (node 17; Figure 27) and came from the π-Aisle (node 16) to have a quick easy access to the π-Aisle (node 8). The truck passes under a smart card reader to consult the authorization database of the truck's multidisciplinary dashboard computer in order to reach the π-Aisle (node 18) and to update the π-System database. The barrier stands for a moment and a message appears on the truck's dashboard computer. It indicates to the driver what he is supposed to do in a near future and the multidisciplinary dashboard computer will show the appropriate path to take. After that, the barrier rises up and gives the access to the driver to move forward in the π-Aisle (node 18).


Figure 27: π-Gate.

18. A truck without trailer came from the π-Gate (node 17) and moves in the π-Aisle (node 18; Figure 28) to have a quick easy access to the π-Aisle (node 8). The carrier drives to the π-Aisle (node 8) to take eventually in charge a road-based trailer in the π-Switch (node 6) in order with his work order.

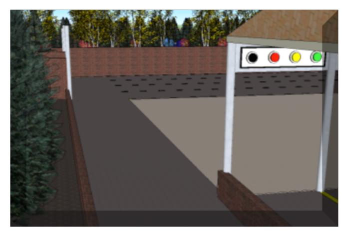
Figure 28: π-Aisle.

19. The π-Aisle (node 19; Figure 29) has been developed for two reasons. First, to allow trucks with or without trailers that entered the π-Transit by mistake to get out of the site. Second, for π-Transit employees to have access to the π-Parking (node 22) next to their working office. These 3 kinds of vehicles come from the π-Aisle (node 3) and going to the π-Gate (node 20). This path is situated next to the entrance of the π-Facility in order to avoid mixing authorized vehicles with unauthorized ones in the critical areas. It is also the quickest way to get out of the π-Transit.


Figure 29: π-Aisle.

20. A truck with or without trailer, or an employee car, came from the π-Aisle (node 19) and is now situated to the π-Gate (node 20; Figure 30). The vehicle passes under a smart card reader to consult the authorization database of the truck's

multidisciplinary dashboard computer or the smart card identification for driver in order to reach the π-Aisle (node 21) and to update the π-System database. Then, two scenarios can occur depending on the type of vehicle:

Figure 30: π-Gate.

a. If it is a truck with or without road based trailer, the barrier of the π-Gate stands for a moment and a message appears on the truck's computer. It indicates to the driver what he is supposed to do in a near future and the multidisciplinary dashboard computer will show the appropriate path to take. After that, the barrier rises up and provides access to the driver to move forward in the π-Aisle (node 21).
b. If it is an employee car, the barrier rises up quickly and provides access to the driver to move forward in the π-Aisle (node 21).

21. Three scenarios might occur in the π-Aisle (node 21; Figure 31) for a truck with or without trailer or an employee car that came by the π-Gate (node 20) or the π-Parking (node 22):

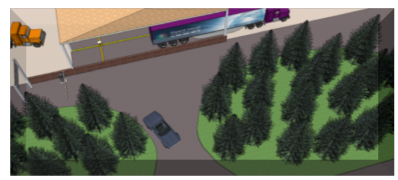

Figure 31: π-Aisle.

    a. A truck with or without trailer entered by mistake in the π-Transit has to drive in direction of the π-Aisle (node 8) in order to reach the π-OutGate (node 14) to exit the π-Transit. In this scenario, the vehicle can only came from the π-Gate (node 20).
    b. An employee starts her/his workday and has to park her/his car in the π-Parking (node 22) next to his office. The car came from the π-Gate (node 20) and moves into the π-Aisle (node 21) in order to reach the π-Parking (node 22).
    c. An employee finished her/his workday and exit the π-Facility or wants to go outside of the π-Transit for a short time and come back after it. She/he has to leave the π-Parking (node 22) next to his office and enter the π-Aisle (node 21) in order to reach the exit of the π-Transit. To do so, she/he will have to pass through the π-Aisle (node 8) and the π-OutGate (node 14) to reach the road.
22. An employee car is parked in the π-Parking (node 22; Figure 32). The π-Transit employee can leave the car there until she/he works in the management and control office or has a good time in the π-Service (node 23). The only way to enter or exit the π-Parking (node 22) is by the π-Circulation Road (node 21).

Figure 32: π -Parking.

23. A driver has parked his truck without trailer in the π-Parking (node 22) and is free to walk in

.

the π-Service (node 23; Figure 33) that provides a green area. This π-Service offers a nice small park containing trees, benches, picnic tables, green spaces, flags of the country and a statue in the center. This area provides the social development aspect of the π-Transit. The π-Service (node 23) is only accessible by the π-Parking (node 22) and allows employees of the π-Transit to have access to the management and control office.

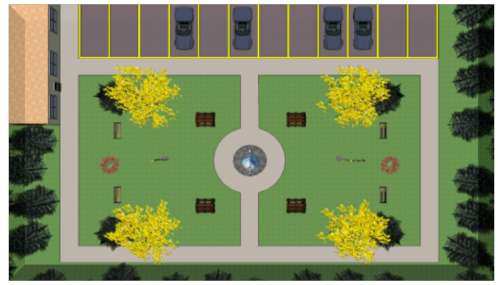

Figure 33

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