Integrating the Generalized-Honeycomb-Torus for Sustainable Parking Structures in the Globalizing Age

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Abstract—Considering disaster sensitivity especially in developing large-scale, multiple-use parking structures, we propose dual-surveillance based SCADA (supervisory control and data acquisition) networks modeled from Generalized Honeycomb Tori -i.e. GHT(m,n,0)/GHT(m,n,n/2), which are proved 1-edge hamiltonian if n≥4; 1_p-hamiltonian if n≥6 or m=2, n≥4, m and n can be specified in a node matrix for a parking structure. These networks are optimal-degree and have nodes'/links' fault-tolerance. They are aimed to be spatially integrated with the helix circulation. Their sequential-order hamiltonicity can benefit systematical maintaining/repairing in parking structures. Moreover, they can benefit energy saving, human-center image and safety/security owing to their efficiency and reliability. Besides, referring to NFPA parking code, instead of the sprinkler, such highly reliable security systems can potentially be adopted as alternative fire-protection methods to prevent water damages; hence, they can help provide flexible land-uses, including logistic distributing places. Therefore, their adaptability and reliability can benefit sustainable urban development.

Keywords: Fault tolerance, Intelligent networks, SCADA systems, Transportation

1.0 Introduction

In this paper, we introduce basic terms related to generalized honeycomb torus first, then we discuss its application to parking structures.

1.1 Definition

Usually, computer and communication networks are represented by graphs where nodes represent processors and edges represent links between processors. In this paper, the graph representation we follow [2]. Let $G = (V, E)$ is a *graph* if V is a finite set and E is a subset of $\{(a, b) | (a, b)$ is an unordered pair of $V\}$. We say that V is the *node set* and E is the *edge set* of G. Two nodes a and b are *adjacent* if $(a, b) \in E$. A *path* is a sequence of nodes such that two consecutive nodes are adjacent. A path is delimited by $[x_0, x_1, x_2, \ldots x_{n-1}]$. A path is called a *hamiltonian path* if its nodes are distinct and span V. A *cycle* is a path of at least three nodes such that the first node is the same as the last node. A cycle is called a *hamiltonian cycle* if its nodes are distinct except for the first node and the last node and if they span V. A graph is called *hamiltonian* if it has a hamiltonian cycle. A graph $G=(V, E)$ is *1-edge hamiltonian* if $G - e$ is hamiltonian for any $e \in E$. A hamiltonian bipartite graph G is 1_p*-hamiltonian* if $G - F$ remains hamiltonian for any $F= \{a, b\}$ with $a \in A$ and $b \in B$ where A and B are the bipartition of G.

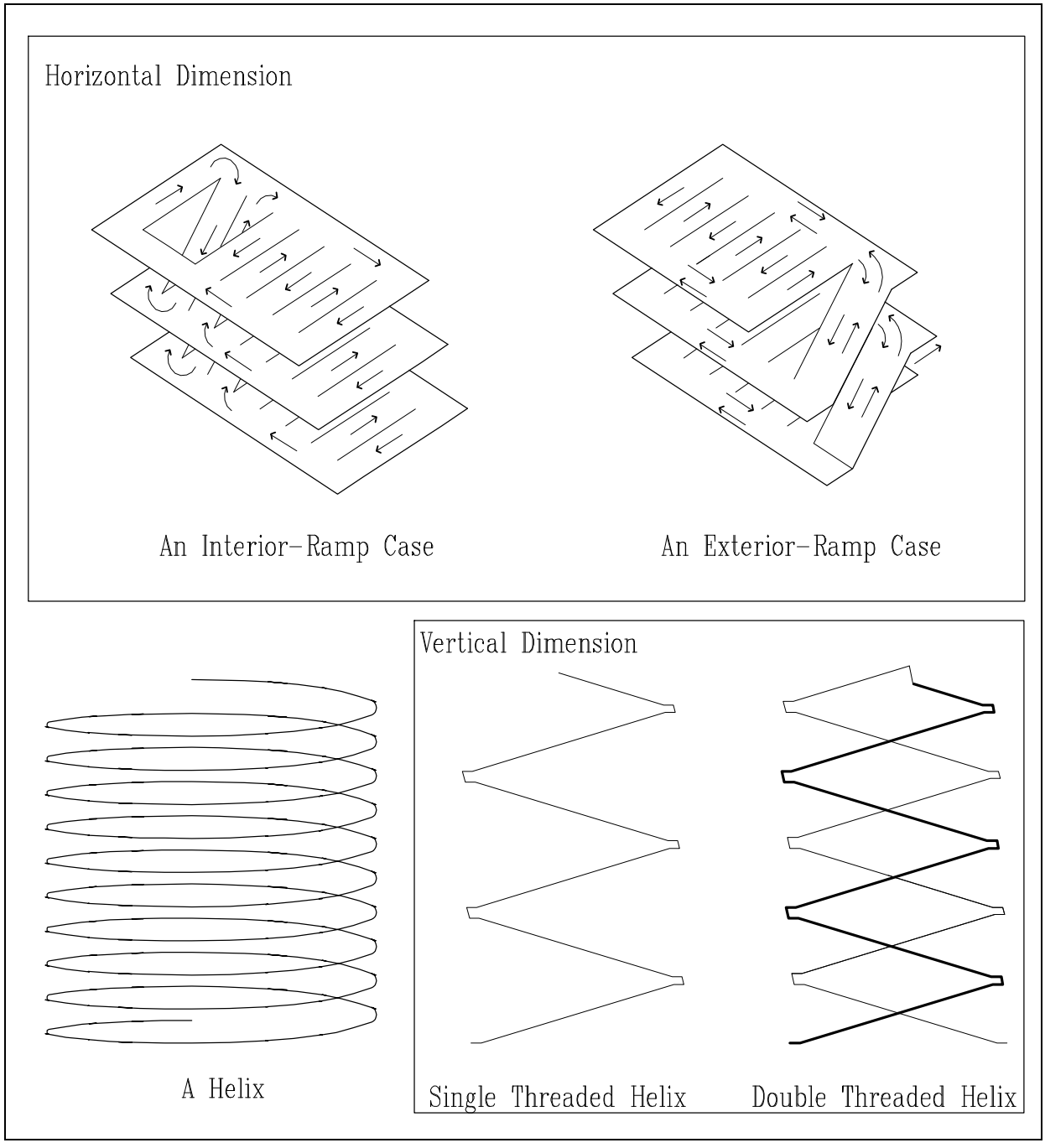

Figure 1. Floor-to-Floor Helix Circulation for Both Users & Managers

The generalized honeycomb torus is defined as the following. Assume that m and n are positive integers where n is even. Let d be any integer such that $(m-d)$ is an even number. The *generalized honeycomb rectangular torus, GHT(m,n,d)* is the graph with the node set $\{(i,j) | 0 \le i < m, 0 \le j < n\}$ such that (i,j) and (k,l) are adjacent if they satisfy one of the following conditions: (1). $i=k$ and $j = l \pm 1 \pmod{n}$; (2). $j=l$ and $k=i-1$ if $i+j$ is even; and (3). $i=0$, $k=m-1$, and $l=j+d \pmod{n}$ if j is even.

When *d=0*, *GHT(m,n,0)* can possibly be called *honeycombed rectangular torus HReT(m,n)*, when *m* and *n* are positive even integers [3, 4]. *HReT(m,n)* is the graph with the node set *{(i,j)| 0 ≤ i < m, 0 ≤ j < n}* such that *(i,j)* and *(k,l)* are adjacent if they satisfy one of the following conditions. (1). *i=k* and *j = l±1(* **mod** *n)*;and (2). *j=l* and *k=i-1(* **mod** *m)* if *i+j* is even.

It is proved that *GHT(m, n, 0)* or *HReT(m,n)* is *1-edge hamiltonian*, if *n≥4* and 1_p-hamiltonian, if *n ≥6* or *m=2*, *n≥4* [3, 4], and when *m* and *n* are positive integers with *n* and *m-n/2* being even, *GHT(m, n, n/2)* is proved *1-edge hamiltonian* if *n ≥4* and *1_p-hamiltonian* if *n ≥6* or *m=2*, *n≥4* [10].

Thus, the fault-tolerance we engaged on is systematically based.

1.2 Application

The design of accessible and safe infrastructure is a political and economical issue, especially since anti-terrorism has been becoming global concern [1]. "Wayfinding is the ability to understand where you are and to find where you want to go in a building and then to recollect the path of travel when departing", and it is a major circulation concern of parking structures for both users and owners in many functional aspects. Generally, the helix circulation pattern has been recommended for dealing with the wayfinding issue [6] (Figure 1). Although, the electronic auto-guidance system can help parking-garage users get their orientation now, the helix circulation pattern is still a good and a passive strategy for security management, owing to its simple continuity-order [1, 15].

Some parking supplies, often near the airports, are toward the large-scale and multiple-use garage pattern, due to technological and economical development. They are being demanded to provide information of the available spaces, location, expected time or cost for potential users, and may be planned as part of the whole intelligent transportation system (ITS). However, the large-scale parking structure is rather disaster sensitive due to relatively less compartment-protection mechanism intrinsic in this building type. Therefore, some of them, especially after the September 11 event, indeed need careful concern in contra-terrorism, providing humanism environment, and critical real-time satisfying services.

Therefore, a SCADA (supervisory control and data acquisition) network integrated with the helix circulation and with distributed intelligence is worthwhile for managing the large-scale parking structure.

2.0 Significance

2.1 Developing Dual-Surveillance Based Networks

However, massive networks having relatively high probability of failure especially require a real-time fault-tolerance mechanism. In addition to fault tolerance, the dual-surveillance system can be featured with better functionality just as the human beings can have better vision by two eyes instead of by one (and node fault-tolerance, [7]).

Thus the proposed SCADA network prototypes in this article are dual-surveillance based, with optimal degree (three connected links to a node) and have both nodes' and links' fault tolerance." We configure so-called GHT(m,n,0) and GHT(m,n,n/2), which are mathematically classified in the Generalized Honeycomb Tori (GHT), for the aforementioned networks as the prototype, and m and n are the scope of a node matrix in a parking structure (Figure 2, 3). Their quality inherent hamiltonian properties, such as "token-passing" approach in information processing, have been proved, and both configurations are proved having high fault tolerance for either nodes or edges [3, 4, 10]. Fault tolerance indeed has already been proposed in newly established large-scale parking structures based on the information via the internet. In this paper, the fault tolerance which we are engaged in, does not only mean some redundancy, but is a systematic and beneficial property with mathematical proof.

Such a fault-tolerant GHT-SCADA network, which is integrated with the helix circulation pattern of parking structures, can have high reliability and can be spatially featured with related services, including direction guiding, and security protecting. This naturally sequential-order hamiltonicity can also benefit systematical managing or repairing in the parking structures. Therefore, this highly reliable network can benefit energy saving, human-center image and safety /security.

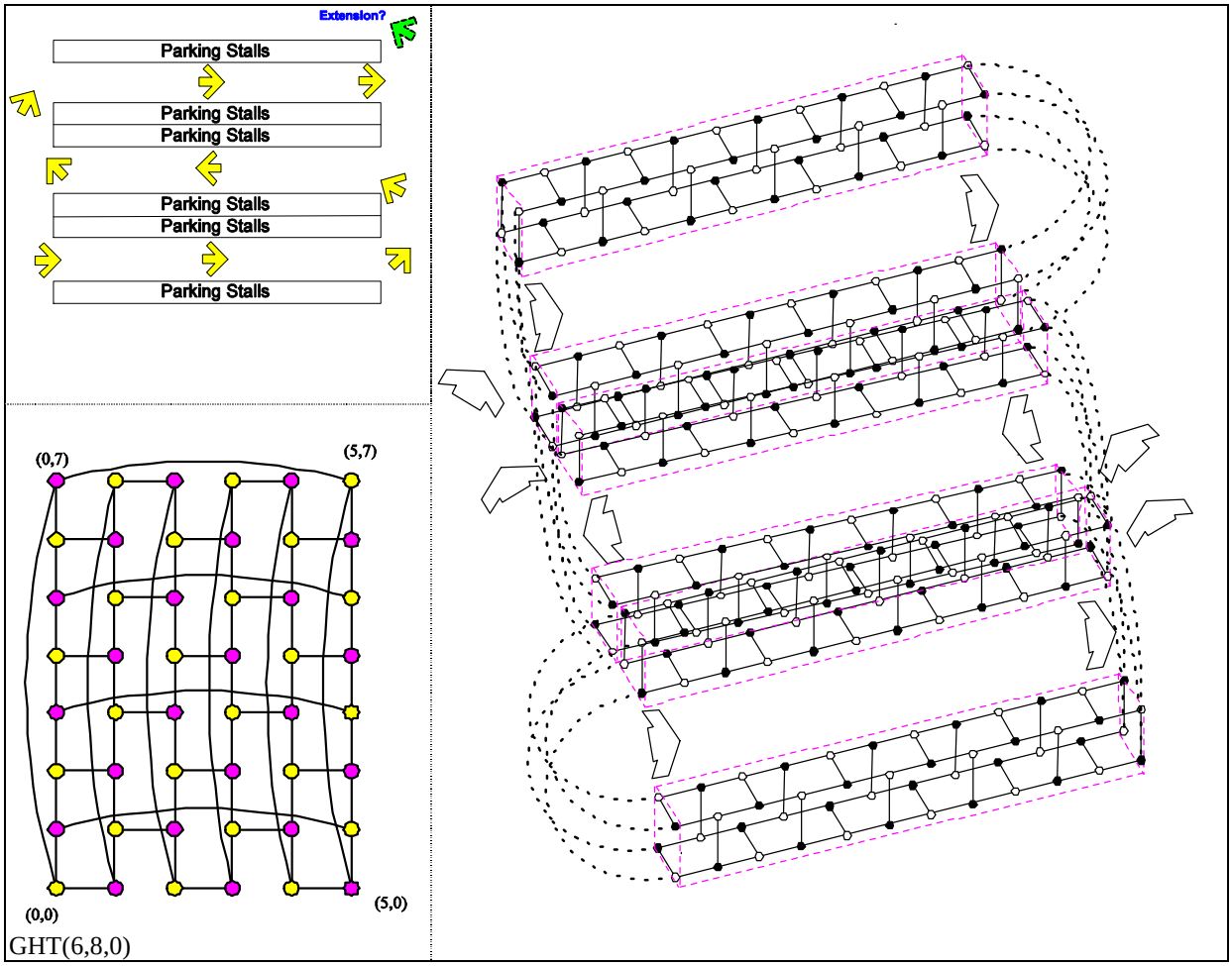

Figure 2. Integration of GHT(m,n,0) with Helix Circulation

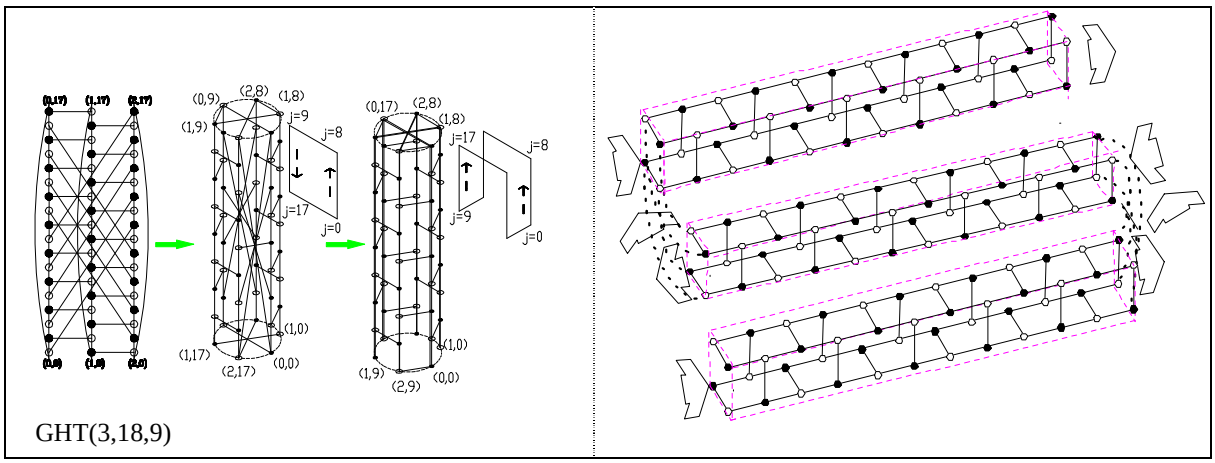

Figure 3. Integration of GHT(m,n,n/2) with Helix Circulation

In addition, as we are now in a rapid aging world, parking-structure design should concern more on providing demand-responsive environments especially for the elderly and the handicapped [6, 14]. Hence, considering the aforementioned highly reliable SCADA networks can help offer continuous and thoughtful cares for protecting parking-structure users. From the vision of human welfare, making pedestrian travel safe and accessible is deemed as an important element for future urban infrastructures [18], and it can benefit the economical development of places [11].

2.2 Ideal Height with Freight Distribution

We need consider the story height for carrying the elderly or the handicapped by the van. The clear height of an ideal (i.e. level of service is A / LOS-A standard) parking garages should be higher than nine feet. Moreover, airport parking structures are typically hoped to design with the LOS-A standard [6].

Such an environment can offer another beneficial possibility because parking spaces are potentially able to provide an alternative place for freight distributing [16]. It should be mentioned that there is a trend to use smaller truck with low floor and low noise in the city which may be congested in sometime or at somewhere [13, 16]. Smaller truck-capacity can well coordinate with high frequency as the strategy, since timing is a very important issue for contemporary freight services. Some small trucks, featured with facilitating embarkation and disembarkation, are being developed, for example: Hino Dutro, which is advertised to be the ideal truck for urban distribution in the 21st century (www.hino.co.jp).

Moreover, it is especially important for air-freights which generally use smaller containers (or ULDs) and have a high-profile growth rate now [17]. Air cargo containers are mostly designed for using in the lower deck of the airplane, and their height is restricted by sixty-four inches [19]. Therefore, by using small trucks, air-freight can potentially be handled in our proposed parking spaces. In this paper; however, we consider the feasible pattern for freight distribution; more specifications are needed to consider, such as conditions for different goods or vehicles.

2.3 More Caring, More Adaptability for the Future

Strategically keeping freight in transportation modes instead of warehousing or inventory stocking often can help save the total cost. Hence, from the perspective of place marketing or regional planning, providing coordinative and flexible alternative spaces for freight handling is a good strategy for developing the place. Besides, we also consider this proposal from the sustainable point of view. If we do not consider providing enough freight handling spaces as an infrastructure element, growing city logistics may be toward using some street spaces for freight handling. Therefore, some bad situations can be expected, such as ruining pedestrian space / quality, or even urban sprawl which is seriously deemed as getting the land-use cancer [8].

Furthermore, the new NFPA (National Fire Protection Association) parking code [12] is being promoted using reliable fire prevention system instead of overly counting on the sprinkler system. This kind of highly reliable network system can help prevent potential water damages through careful security design. Besides, our proposed networks can coordinate with new technology, such as RFID (radio frequency identification, [9]); hence, the proposed parking space can be an adaptable platform, or can be used for crossdocking, which is based on well integrating information, facility (including to concern both fire protection and water damage) and transportation [5].

Moreover, owing to the flexible and reliable nature, the proposed networks for parking structures can provide more adaptable means for other possible uses or multiple-uses, for examples: logistic stations, museums, offices or taxi / paratransits' parking spaces. Therefore, the proposed networks can be helpful for urban development in a sustainable way.

3.0 Conclusion

The parking supply is being built toward large-scale garages globally. They are demanded to provide information of the available spaces, location, expected time or costs for potential users, and may be planned as parts of the whole intelligent transportation system. However, especially after the September 11 event, the large-scale pattern is indeed need careful concern in contra-terrorism, providing humanism environment, and critical real-time satisfying services.

Hence, a SCADA (supervisory control and data acquisition) network with distributed intelligence is worthwhile for integrally managing the large-scale parking structure. Moreover, massive networks having relatively high probability of failure especially need a real-time fault-tolerance mechanism. In addition to fault-tolerance, the dual-surveillance

system can be featured with better functionality just as the human beings can have better vision by two eyes instead of by one (and node fault-tolerance). Therefore, the proposed SCADA network prototypes are dual-surveillance based, with optimal degree (3 connected links to a node) and have both nodes' and links' fault tolerance.

The Generalized Honeycomb Tori, GHT(m,n,0) and GHT(m,n,n/2) have been prototyped for the aforementioned networks. Their quality inherent hamiltonian properties, such as "token-passing" approach in information processing, have been proved. Such a GHT-SCADA network is aimed to be spatially integrated with the helix circulation pattern of parking structures, and featured with related services. This sequential-order hamiltonicity can also benefit systematical maintaining or repairing in the parking structure. Therefore, this highly reliable network can benefit for energy saving, human-center image and safety / security.

Besides, referring to the new NFPA parking code, such highly reliable security systems potentially can be adopted as alternative fire-protection methods instead of overly counting on the sprinklers in order to prevent water damages. Therefore, they can provide more flexible means for other possible uses, for examples: logistic distribution stations, museums, offices or taxi / paratransit parking spaces. Furthermore, their adaptability and reliability can be helpful for urban development in a sound and sustainable way.

4.0 References

[1] Paul Arthur and Romedi Passini, *Wayfinding – People, Signs, and Architecture*, p. 74, McGraw-Hill, 1992.

[2] J.A. Bondy and U.S.R. Murty, *Graph Theory with Application*, North-Holland, New York, 1980.

[3] Hsun-Jung Cho and Li-Yen Hsu, "Generalized Honeycomb Torus", *Information Processing Letters*, vol. 86-4, pp. 185-190, 2003.

[4] Hsun-Jung Cho and Li-Yen Hsu, "Ring Embedding in Faulty Honeycomb Rectangular Torus", *Information Processing Letters*, V0l. 84-5, pp. 277-284, 2002.

[5] Sunil Chopra and Peter Meindl, *Supply Chain Management: Strategy, Planning and Operation*, Prentice Hall, pp.51-57, 2001.

[6] A. Chrest, M. Smith, S. Bhuhan, D. Monaham, and M. Igbol, *Parking Structures*, 3rd, Kluwer, pp. 40-48, p. 375. 2001.

[7] A. Chrest, M. Smith, and S. Bhuhan, *Parking Structures*, 2nd, VNR, the picture in p.127, 1996.

[8] Simon Eisner, Arthur Gallon, and Stanley Ensner, *Urban Pattern*, 6th, McGraw Hill, p.284, 1993.

[9] Klaus Finkenzeller, (translated by Rachel Waddington), *RFID Handbook: Radio Frequency Identification Fundamentals and Applications*, Wiley, p. 22, 1999.

[10] Li-Yen Hsu, Feng-I Ling, Shin-Shin Kao and, Hsun-Jung Cho, "Ring Embedding in Faulty Generalized Honeycomb Tori", submitted for publication, 2005.

[11] P. Kotler, D. Haider, and I. Rein, *Marketing Places*, Free Press, p. 253, 1993.

[12] National Fire Protection Association, *NFPA 88A Standard for Parking Structures* 2002 ed., NFPA, item 6.2, 2002.

[13] John Niles, Trucks, *Traffic, and Timely Transport: A Regional Freight Logistics Profile*, a publication of the Mineta Transportation Institute, College of Business, San José State University, San Jose, CA 95192-0219, transweb.sjsu.edu/ publications / Freight.htm, 2003.

[14] G. Papacostas and P. Prevedouros, *Transportation Engineering & Planning*, 3rd, Prentice Hall, p. 271, 2001.

[15] Romedi Passini, *Wayfinding in Architecture*, VNR, p. 48, p.106, 1992.

[16] G. Pivo, D. Carson, M. Kitchen and D. Billen, "Learning from Truckers: Truck Drivers' View on the Planning and Design of Urban and Suburban Centers", *J. of Architectural & Planning Research*, Vol.19, No. 1, pp. 13-29, 2002.

[17] Stephen Shaw, *Airline Marketing and Management*, 5th ed., Ashgate, pp. 41-45, 2004.

[18] Martin Wachs, "Mobility for California's Aging Population", *CPRC Brief*, No.6, Institute of Transportation Studies, University of California, Berkeley, 2001.

[19] World Trade Press, *Encyclopedia of International Trade*, http://www.fredoniainc.com/glossary.

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