Journal of the Ergonomics Society of Korea
Vol. 29, No. 4 pp.647-654, August 2010 DOI:10.5143/JESK.2010.29.4.647

Development of Evaluation Metrics for Pedestrian Flow Optimization in a Complex Service Environment Based on Behavior Observation Method

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ABSTRACT

In a service environment, the spatial layout is an important factor that has a great impact on customers' behavioral characteristics including wayfinding and purchasing. Previous studies have shown a gap between marketing, focusing solely on profitability and satisfaction, and architecture, looking only into efficiency of pedestrian flow. To balance such disparity, this study suggests an integrated approach for assessing behavioral patterns in complex service environments. With the objective that complex service environments should aim to increase its profitability and efficiency while guaranteeing customer satisfaction, quantitative metrics was developed for evaluation. The metrics was defined to use data from behavior observation including path tracking, population counting, and gaze analysis, while previous studies have relied on abstract survey methods that were prone to sampling errors and loss of data. For validation of the metrics in a real world setting, a case study was conducted at 4 train stations in Korea. In the case study, experiments were conducted to gather the required data in all 4 train stations, while their physical layouts were also analyzed. With the results from the case study, comparative evaluation of the 4 train stations in terms of behavioral efficiency was possible, together with a discussion on the effect of their physical settings.

Keywords: Efficiency of pedestrian flow, Evaluation metric, User observation, Servicescape, Complex service environment

1. Introduction

Service environment is the physical environment in service businesses that are likely to influence behaviors and create an image of the business (Bitner, 1992). In service processes, the physical environment in which the process takes place is known to have impact on consumers' perception of service quality, purchase behavior, and satisfaction on the process (Booms and Bitner, 1981; Bitner, 1992; Wakefield and Blodgett, 1996; Wakefield and Baker, 1998; Cockrill et al., 2008). Particularly, when a service process is being operated in a large and complex environment, the effect of the spatial layout on users' behavioral characteristics in terms of pedestrian circulation and flow also becomes an important issue (Wakefield and Blogett, 1996; Yoo, 1996; Choi and Min, 1998; Wakefield and Baker, 1998; Choi and Min, 2002; Park et al., 2003; Choi and Lim, 2004; Lee et al., 2006). As types of service environment become more diverse and their physical settings become more complex, it is essential to study further into finding the impact of service environment on consumer behavior.

The term 'servicescape' has been used in many research papers for describing and emphasizing the role of physical environment in a service process. Booms and Bitner (1981) defined a servicescape as "an environment in which service is assembled and in which the seller and customer interact,

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combined with tangible commodities that facilitate performance or communication of the service." In a marketing point of view, researches have been focusing on customers' satisfaction and desire to stay. In an architectural point of view, researches on the complex physical layout, environments, and wayfinding were studied.

Recently, Service environments are becoming larger and more complex while adopting multiple functions. Thus, the integrated approach is needed to assess the new service environments effectively and efficiently. This study aims to propose quantitative metrics to assess customer behavior and pedestrian flow in complex service environment. Also, the metrics was applied to train stations for empirical verification.

2. Literature survey

2.1 Servicescapes: the physical settings in service environments

Servicescape is a term developed to suggest the impact of a service environment's physical setting on customers' behavior and attitude toward the service (Booms and Bitner, 1981). Many studies have empirically examined the influence of physical settings' spatial layout and functionality on human behavior. Wakefield and Blodgett (1996) identified dimensions of a servicescape by studying baseball stadiums. Similar efforts were shown in later studies on more various types of leisure service settings including casinos and restaurants (Lucas, 2003; Kim and Moon, 2009). Since the concept of servicescape was first developed as a marketing terminology, previous researches have focused only on a limited range of aspects of user behavior. Since the concept leaves out some important environmental characteristics such as architectural structure of a servicescape, results of previous studies cannot be applied in the early stages of building a service environment.

2.2 Spatial layout and user behavior in complex service environments

The spatial layout and functionality of servicescape are highly salient to customers in environments where customers have to perform on their own without any assistance from employees. They are more important in complex settings than in simple surroundings (Bitner, 1992). Since complex servicescapes are usually more complicated in terms of layout, they have not only been considered in marketing and business management, but also in the field of architecture. In a research of Choi and Baek (2002), it was suggested that spatial layout affects the overall efficiency of wayfinding in shopping malls. They found that within a complex service environment, the spaces that are well integrated and connected with other parts of the environment were more easily and frequently reached by customers. The integration of spaces within a complex service environment was found as an important factor of spatial layout that affects user behavior, especially pedestrian circulation and flow in the environment, in other studies as well (Park et al., 2003; Lee et al., 2006).

In today's society more service environments, such as train stations, sports arenas, airports and hotels, are becoming multi-functional. Thus, more research is needed to empirically study how the physical setting of a complex service environment, especially the spatial layout and functionality, influence user behaviors such as their circulation and flow in the structure.

2.3 Quantitative evaluations on service environments

Quantification of user behaviors has been investigated in other related research areas. In transportation science, quantitative assessment was done to analyze the effects of physical settings on transportation routes and time (Braess et al., 2005; Jin et al., 2008; Papadimitriou et al., 2009; Stepanov and Smith, 2009). Service has also been a research topic for quantitative evaluation, but previous analyses have been limited to the concept of service process and its productivity (Gronroos and Ojasalo, 2004).

For evaluation of user behavior in service environments, many previous studies have approached the topic with qualitative measurements and methods (Wakefield and Blodgett, 1996; Lee et al., 2006; Cockrill et al., 2007; Park et al., 2008; Kim and Moon, 2009). Qualitative methods such as interviews and surveys are useful in assessing user satisfaction, especially when marketing management is the main concern. However, in complex service environments, where the interactions between users and the architectural space layout is considered as an important issue, quantitative

measurements are needed for systematically evaluating user behavior (Yoo, 1996).

Previous studies have developed models and metrics to assess efficiency of pedestrian flow effectively. However, they were limited in considering patterns in pedestrian circulation and finding relationships with spatial layouts. Also, many of the metrics have been studied in laboratory settings or simulated environments. Thus, more comprehensive and empirical studies are needed for development of metrics with enhanced generalizability and validity.

2.4 The need for an integrated approach

As a result of literature survey, different definitions of user behavior were found between the views of marketing and architectural engineering. Most of the studies in the field of marketing focused on users' satisfaction, feeling of commitment, and desire to stay. On the other hand, studies in the field of architecture were more focused on complex physical settings and had defined user behavior in terms of wayfinding.

Along with the definitions significantly differing from the two points of view, the objectives set from each view on building service environments also showed some differences. Recently, service environments are becoming larger, getting more complex, and adopting multiple functions (Choi and Baek, 2002). Thus, an integrated approach with a comprehensive set of objectives and quantitative measurements is needed to minimize the gap between the two viewpoints.

3. Development of an evaluation metric

3.1 Objectives for integrated framework

As described in 2.4, objectives in views of marketing and architecture in building a complex service environment differ significantly. However, the gap between the two fields should be minimized for more practical use.

In this study, new objectives were defined in order to develop an integrated evaluation metrics for evaluating today's complex service environments. The specific objectives largely state that today's complex service environments should aim to increase its profitability and efficiency while guaranteeing user satisfaction. In other words, complex service environments must enable users to effectively explore and move through the physical settings, encourage them to get involved in purchase activities, and satisfy them fully. The new integrated set of objectives is stated in Table 1.

3.2 New metrics for complex service environments

Although previous studies have suggested several quantitative metrics for evaluating user behavior, such metrics cannot fully assess the degree in which a complex service environment satisfies the objectives stated in Table 1.

For a more comprehensive evaluation, this study suggests new metrics applicable to various types of complex service environments. The developed metrics aims to assess the degree to which the spatial layout of a complex service environment satisfies the objectives stated in Table 1. The proposed metrics includes both objective and subjective measures, all defined in quantitative terms. The descriptions and operational definitions are summarized in Table 2. In order to apply the metrics, objective and subjective empirical survey will be needed for the environment in concern. Possible techniques for such empirical research are suggested in the last column of Table 2.

Unlike previous studies that have focused heavily on measuring flow efficiency, the metrics described in Table 2 covers other aspects of complex service environments. With the comprehensive list of metrics, the degree in which a complex service environment fulfills the objectives in Table 1 can be extensively evaluated.

4. Case study: behavioral efficiency in complex train stations

In this study, 4 major train stations in Korea - Seoul, Yongsan, East Daegu and Yongdeungpo Station - were selected for experiment. The 4 stations have similar size, complexity, and average number of passengers. All 4 stations hold multiple types of trains including Korea eXpress Train (KTX), regular transit lines, and subway lines.

For evaluation of the 4 stations with the metrics

Table 1. Objectives suggested in this study

1st level	2nd level	3rd level	Description
Increasing profitability	Increasing exposure of profitable places (P1)		Placing stores near main flow routes to increase the exposure rate
	Guiding more people to profitable places	Guiding flow by functional layout (P2)	Distributing stores at proper locations in relation to other functional spaces so that the customers are guided to them
		Guiding flow from outside the building (P3)	Designing the exterior of the building so that the customers outside the building are guided inside
	Inducing purchase activities (P4)		Increasing purchase activities by characterizing the stores considering customer behavior and preferences
Enhancing flow efficiency	Increasing wayfinding efficiency	Balancing flow population (E1)	Making the circulation load more even throughout various routes by diversifying main routes and placing exits at proper places
		Reducing flow collisions (E2)	Smoothing the flow out and decreasing congestion by removing potential bottlenecks and blockages
	Minimizing flow congestion	Enhancing layout understandability (E3)	Reducing the potential of getting confused or lost and making wayfinding more efficient in terms of time and error frequency
		Increasing signage suitability (E4)	Placing signs at proper places to help customers find their way easily and efficiently

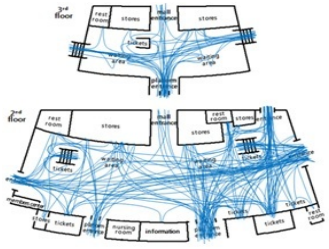

Figure 1. Path tracking data for Seoul Station

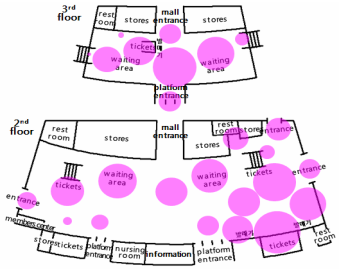

Figure 2. Population counting data for Seoul Station

developed, experiments were conducted to gather the data needed. Experiments were conducted in 4 parts, including path tracking, population counting, eye gaze recording, and passenger survey. Methods of each experiment are summarized in Table 3. The experiments were done for all of the 4 stations. Since purposes of visit and crowdedness of the environments can differ due to time and day, the experiments were done at a similar time during a weekday.

Figure 3. The device for recording eye gaze data

4.1 Results of the case study

After collecting data from 4 parts of the experiment, results for all the metrics defined in Table 4 were calculated. The data gathered were organized and aggregated to produce evaluation results for all 4 train stations in terms of the metrics. Results from evaluation are summarized in Table 4, where the bold numbers represent the best of the 4 stations. The results showed that Seoul Station and East Daegu Station outperformed the other two stations when evaluated on the environments' tendency to increase profitability. Places that generate profits were exposed more openly to passengers in and out of the building at East Daegu Station. At Seoul Station, profitable places with more suitable characteristics were well connected to other functional areas in the station, and were also seen and located more easily by passengers. Seoul Station and East

Table 2. New metrics for evaluating complex service environments

1st level	2nd level	3rd level	Measurement	Description	Operational definition	Requirements
Increasing profitability	Increasing exposure of profitable places		Rate of exposure (time)	The percentage of time a customer walks by stores as the customer moves through an environment	(Average time a customer walks by stores) / (total time during a path)	Path tracking data
			Rate of exposure (population)	The relative crowdedness around stores compared to other places	(Average number of people near stores) / (average number of people at other places)	Count data
			Location perceptibility	The relative perceptibility of stores compared to other places	(Average perceptibility score of stores) / (average perceptibility score of other places)	Survey results
			Share of gaze amount	The percentage of time spent looking at stores as a customer looks at various places in an environment	(Time spent looking at stores) / (total time of gaze recording)	Gaze recording data
	Guiding more people to profitable places	Guiding flow by functional layout	Relative store dispersion	Thorough dispersion of stores relative to other main functional service facilities	Average number of stores placed next to or across from each main functional service facility	Layout information
			Connection to main routes	Frequency of additional purchase activities occurring on main routes	Average number of additional purchase activities occurring on main routes	Path tracking data
			Connection to main functional service places	Frequency of additional purchase activities relative to essential purchase activities	(Average number of additional purchases per customer) / (Average number of essential purchases per customer)	Path tracking data
		Guiding flow from outside the building	Connection to outside passengers	The percentage of outside passengers being guided into an environment	(Number of passengers moving into the building) / (total number of people walking by the building)	Path tracking data
			Attention from outside	The degree of attention drawn to stores in the environment when seen from the outside	Average number of times a passenger looks into the building from the outside	Gaze recording data
	Inducing purchase activities		Suitability of store characteristics	The ratio of actual purchase activities to the number of times a customer enters stores	(Average number of purchase activities) / (average number of customers walking into each store)	Survey results, count data
Enhancing flow efficiency	Minimizing flow congestion	Balancing flow population	Flow concentration	The relative crowdedness at populated places compared to places without many customers around	(Average number of people at the 3 most crowded spots) / (average number of people at the 3 least crowded spots)	Count data
			Route diversity	The degree of variety in the paths customers take	Number of main routes taken by more than 5% of all sampled customers	Path tracking data
		Reducing flow collisions	Collision frequency	The percentage of number of spots prone to collisions in an environment	(Number of spots with frequent occurrences of bottlenecks and blockages) / (total number of counted spots)	Path tracking data
			Collision severity	The severity of collisions that occur in an environment	Average time taken to pass through areas with bottlenecks and blockages (seconds)	Count data
	Increasing wayfinding efficiency	Enhancing layout understandability	Wayfinding error rate	The frequency of errors occurring as customers find their way	Average number of times a customer shows hesitance or moves in a wrong direction	Path tracking data
			Wayfinding completion time	The time taken for a customer to find way through an environments	Average time taken on a path (minutes)	Path tracking data
			Functional layout perceptibility	The relative perceptibility of main service functional places compared to other places	(Average perceptibility score of places with main service functions) / (average perceptibility score of other places)	Survey results
		Increasing signage suitability	Signage understandability	The time taken for a customer to understand the contents in a sign	Average time taken on reading a sign before making directional changes (seconds)	Gaze recording data
			Time for locating signs	The time taken for a customer to find specific signs in need	Average time taken on gazing through the view to find a proper sign (seconds)	Gaze recording data

Daegu station differ from the other 2 stations in their structural characteristics. While the other two stations have a wide open area where passengers move freely in many directions, Seoul Station and East Daegu Station has a long hallway where passengers move back and forth. It can be inferred that such spatial layout maximizes passengers' attention and flow toward profitable places.

Considering the passengers' flow efficiency, Yongsan Station was evaluated to be the best in most of the metrics. At Yongsan Station, the flow was more balanced with a less occurrence of collisions. Also, the layout and signs were more easily understood by passengers. Since the spatial layout of Yongsan Station was more open and mixed compared to the other stations, passengers could move freely into various directions, looking at various places in the building. Thus, it can be thought that the structural

Table 3. Experiment methods

Method	Description	Devices
Path tracking	Drawing the movement path by following passengers who are randomly selected(see Figure 1)	Map of the station with its physical layout
Population counting	Partitioning the area of the station into functional spaces and calculating the average number of people within the spaces after counting(see Figure 2)	Bird's-eye-view cameras
Eye gaze recording	Recording the gaze point of passengers with a small camcorder(see Figure 3)	A camcorder connected to a micro-sized portable lens
Passenger survey	Having the passengers evaluate on their perception of and attitude towards the station(435 participants, male: 214, female: 221)	Questionnaires

Table 4. Results from evaluation experiment

1st level	2nd level	3rd level	Measurement	Seoul	Yongsan	East Daegu	Yongdeungpo
Increasing profitability	Increasing exposure of profitable places		Rate of exposure (time)	0.46	0.4	**0.6**	0.38
			Rate of exposure (population)	0.19	0.22	**0.23**	0.21
			Location perceptibility	**1.18**	1.01	**1.18**	1.03
			Share of gaze amount	**0.26**	0.15	0.17	0.2
	Guiding more people to profitable places	Guiding flow by functional layout	Relative store dispersion	**0.88**	0.83	0.75	0.6
			Connection to main routes	1.57	1.57	1.51	**1.64**
			Connection to main functional service places	**0.62**	0.36	0.57	0.41
		Guiding flow from outside the building	Connection to outside passengers	0.37	0.32	**0.64**	0.26
			Attention from outside	0.72	0.4	**0.81**	0.42
	Inducing purchase activities		Suitability of store characteristics	**0.86**	0.62	0.74	0.63
Enhancing flow efficiency	Minimizing flow congestion	Balancing flow population	Flow concentration	7.61	**5.68**	6.59	5.77
			Route diversity	9	**13**	7	9
		Reducing flow collisions	Collision frequency	0.62	**0.44**	0.54	0.59
			Collision severity	6.16	**4.21**	8.35	7.4
	Increasing wayfinding efficiency	Enhancing layout understandability	Wayfinding error rate	2.31	2.6	**1.07**	2.48
			Wayfinding completion time	30.14	**21.35**	27.66	22.04
			Functional layout perceptibility	**1.12**	**1.12**	1.07	1.11
		Increasing signage suitability	Signage understandability	**4.3**	7.61	4.82	7.93
			Time for locating signs	4.59	**3.11**	5.86	6.2

characteristics partly caused passengers to form flows in various ways. Also, since the station had a large open area, collisions did not interfere with the flow too much.

5. Discussion and conclusion

Service environments are becoming more complex and multi-functional. Previous studies have tried to assess user behavior solely in the marketing's viewpoint or architectural one. While marketing and architecture have different views, this study suggested an integrated approach. To overcome the limitations of qualitative approach, quantitative metrics was developed to evaluate complex service environments in various dimensions. Using the metrics developed, train stations were evaluated as complex service environments. Results from evaluation were discussed with relation to the stations' spatial layouts.

This study suggests evaluation metrics to assess pedestrian flow and user behavior in complex service environments quantitatively. The limitation of this study is that only train stations were concerned for the applying developed metrics and only qualitative verification was done. In the future research, quantitative validation, such as revenue analysis or satisfaction comparison between different service environments, is needed. Also, additional case studies should be carried out.

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Date Received : June 6, 2010
Date Revised : July 22, 2010
Date Accepted : July 22, 2010