International Journal of Control and Automation
Vol. 9, No. 7 (2016), pp.23-38
http//dx.doi.org/10.14257/ijca.2016.9.7.03

Hospital Parking Character and SEM-ML Integration Model of Parking Mode Choice Behavior

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Abstract

A correct understanding of hospital parking characters and parking behavioral regularities is very important to hospital parking planning, making parking management measures and improving the utilization of parking lot. The existing researches in parking behavior concentrate on parking behavior in central area, and the researches on hospital parking behavior are still not deep. Besides, the research methods mainly adopt disaggregate model which only considers driver's observable manifest variables, neglecting the influence of mental latent variables on the results of parking choice, so the model's explanatory ability is weakened. Aiming at the hot issue - hospital parking problem, based on the analysis of hospital parking character, this paper puts forward the latent variables of hospital parking mode choice. By improving the utility function of traditional ML disaggregate model, establishing three kinds of SEM-ML integration model which could describe car drivers' characteristic manifest variables and subjective mental latent variables, and then applying examples to make comparison and analyze. The results show that: Compared with traditional ML model, the SEM-ML model has a better accuracy and explanatory ability. Among the three models, the SEM-ML3 integration model could describe the relationship between latent variables and manifest variables, latent variables and observable variable by structural equation, so it has a better accuracy and explanatory capability. The results validate that manifest variables (parking purpose) and mental latent variables (convenient level and feelings of parking) have effects on hospital parking mode choice. According to the analysis results, this paper proposes corresponding suggestions on planning and managing hospital parking from three aspects: convenience, comfort and safety.

***Keywords**: Static Traffic, Hospital Parking, Parking Behavior, Latent Variable, Structural Equation Model, Disaggregate Model*

1. Introduction

With the improvement of people's living standard and the development of China's medical and healthy undertaking, hospital parking problem is increasingly outstanding. Hospital parking problem has become a part of "difficult medical services" and affect hospital environment seriously. In the long run, the scale of polyclinic tends to large-scale in China. The explosion of outpatients will lead to more parking demands, so the imbalance between supply and demand of hospital parking is sharper day by day.

Parking mode choice behavior is the foundation of hospital making strategies for relieving parking problem, and the understanding of decision-making law of parking behavior is related to the rationality and accuracy of parking site-selecting, type-selecting and scale-forecast. The results of car drivers' parking choice behavior will directly affect the whole efficiency of dynamic and static traffic system in hospital.

ISSN: 2005-4297 IJCA

However, hospitals seek to meet the demands of parking berth quantity blindly, neglecting the study and analysis of parking behavior. This leads to a series of problems, such as bad experience and low operation efficiency.

The existing researches focus on parking mode choice behavior concentrating on two aspects: parking choice behavior in central business district and the influence of parking policy on parking behavior. The latest and classical research results as follows: Martijn B.W. [1] studies the influence of parking fee on car drivers' choice between street parking and garage parking; The study of P. Bonsall and I. Palmer [2] hold that driving experience and parking guidance information have a great influence on parking behavior; By survey data of parking behavior in Xidan Area of Beijing, Doc. Guan Hongzhi adopts disaggregate theory to establish a choice model of parking garage [3] and a choice model of the length of parking time [4]. Yun Meiping [5] studies a scale optimization model of public parking garage considering parking choice behavior. However, researches in hospital parking still rest on these aspects, such as parking facilities planning of the polyclinic [6], investigation on the hospital parking problem [7], reasons and solutions to parking problem [8], but further researches in hospital parking behavior have not been carried out yet.

The existing researches in parking behavior mainly adopt disaggregate theory. This method could only introduce alternative scheme and car drivers' observable variables and it pays more attention to the result of car drivers' choices. Besides, this method doesn't include latent variables, such as car drivers' mental variables of parking choice behavior, ignoring the influence of latent variables, so it can't describe the mechanism of parking choice process [9]. These researches only consider observable variables like parking purpose, the length of parking time, parking fee, driver's gender, age and income level, ignoring the unobservable latent variables like the feelings and service environment of parking. We can't obtain the mathematic model which is close to car drivers' parking choice behavior and choice process, so the model's explanatory ability is weakened.

In view of the above problems, by introducing structural equation model, this paper proposes integration relation which could describe the relationship between car drivers' manifest variables and latent variables, latent variables and observational variables of parking behavior. On this basis, the utility function of traditional Multinomial-logit model is improved to establish the SEM-ML integration model containing latent variables, and then this paper proposes solving steps which applying AMOS, SPSS software to solve the integration model [10]. At last, by the data got from parking behavior questionnaire of grade A class 3 hospitals in China Chongqing, this paper makes case analysis to analyze and compare the accuracy and explanatory ability of traditional ML model and SEM-ML integration model.

2. Hospital Parking Character and the Latent Variables of Parking Choice

Hospital parking character is the foundation of analyzing car drivers' parking mode choice, so this paper firstly analyzes the influencing factors of hospital parking character and eigenvalues, such as degree of parking saturation, parking purpose, the length of parking time, walking distance after parking.

2.1. The Analysis of Hospital Parking Character

As a special kind of urban public buildings, hospital's parking character is different from other public parking and appertaining parking lots. Except for the level of urban motorization, the location condition of hospital and the accessibility of public transportation, the main factors affecting hospital parking character include:

The nature and grade of hospital: In China, according to the nature, hospital can be divided into five types: polyclinic, specialized hospital, special hospital, children's hospital/MCH hospital and sanatorium. Hospitals implement three-level medical system, setting three levels and ten grades. The number of outpatients and the average hospitalizing time are determined by the nature and grade of hospital. Because of good medical condition, overall departments, complete functions and high reputation, generally grade a hospital and A-level 3-class hospital have more outpatients and parking demand.

Hospital scale: The number of hospital beds is the main index to measure hospital scale, and usually the parking demand of hospital is positively correlated with the number of hospital beds. A large-scale polyclinic can offer more types of parking facilities, so the law of parking character is more complicated.

This paper conducts surveys to collect parking data in China Chongqing (Southwest Hospital, Tumor Hospital, The First Affiliated Hospital of Chongqing Medical University), Xinjiang (Bazhou People's Hospital, The Xinjiang uygur autonomous region people's hospital), Xining (The Qinghai University affiliated hospital). As space is limited, this paper analyzes the parking character indexes of Southwest Hospital emphatically, and then compares and analyzes part indexes with other hospitals.

2.1.1. The Degree of Hospital Parking Saturation

The degree of parking saturation means the ratio of parking number to available parking spaces in hospital at a certain time segment or at a given time. This paper takes the number of outpatients and the parking data in Southwest Hospital from 18th the October to 11th the November in 2013 as an example to analyze.

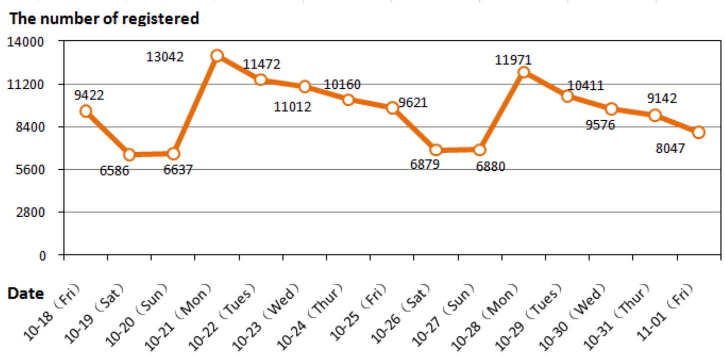


Figure 1. Southwest Hospital Outpatient Registration Index

The daily average number of out-patients in Southwest Hospital is about 9000~10000 person/day, but the available parking spaces in the hospital are about 1700. Figure 2 shows that: The degree of hospital parking saturation is correlated with the business hour. In the morning, the curve reaches the peak of saturation within 1~ 2h after beginning the business, and the fluctuation of parking saturation keeps stable during the business hour, except for the noon time, then decreasing slowly after the close of business. On weekdays, the peak period of parking is in accordance with that of hospitalizing. The parking demand in hospital is large on weekdays, and the law of the seven investigated hospitals is that: the Monday‘s parking demand is maximum, the Friday‘s is minimum, and the weekend’s is stable. On weekdays, the saturation of hospital parking garage is close to or even larger than 100%, and the highest peak of saturation could reach 155% on Monday. It is clear that: the gap of parking spaces in hospital is large. The peak of parking demand is larger than the capacity of inner parking facilities in hospital, and so car drivers could only choose illegal parking.

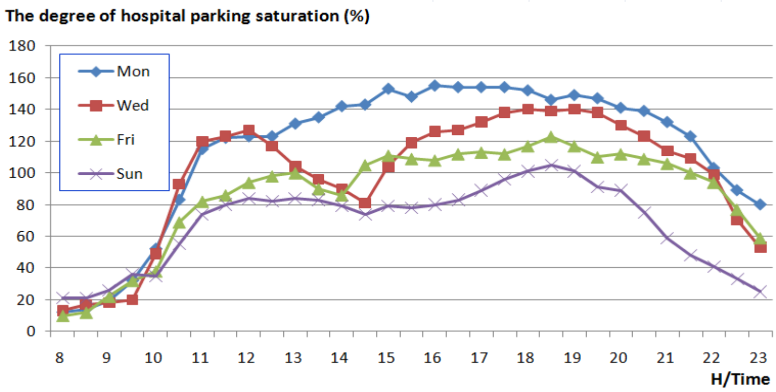
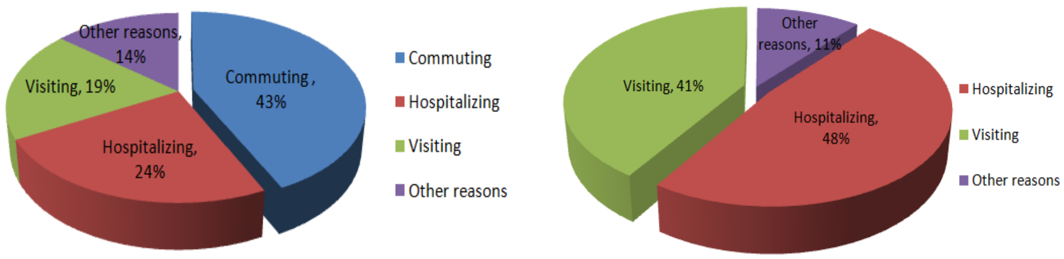


Figure 2. The Degree of Hospital Parking Saturation

2.1.2. Parking Purpose

The composition of parking purpose is related to the hospital scale (the number of beds), the location of hospital, the number of employees, parking fee and the management mode. Generally the parking purposes in hospital can be divided into three types: medical staff whose parking purpose is commuting; patients whose parking purpose is hospitalizing; parking for visiting. Beyond that, there is still little parking for doing business and other reasons. For the aggravation of hospital parking problem, many hospitals adopt the following management mode: restricting the employees' parking to guarantee the patients' parking demand. And this changes the composition of parking purpose greatly. This paper will compare and analyze China Chongqing Southwest Hospital with Chongqing Tumor Hospital which restricts the employees' parking.



a. Southwest Hospital (Parking Free, Unlimited) b. Chongqing Tumor Hospital (Charge, Restricting Employees Commuting Park)

Figure 3. The Proportion of Hospital Parking Purpose

Figure 3 shows that: The parking fee policy and the management measures have great influence on the composition of parking purpose in hospital. Because of Southwest Hospital adopts an unlimited extensive management with free parking, the medical staff for commuting occupied parking spaces for a long time, the turnover rate of parking is low. And the around social vehicles increase the proportion of non-hospitalizing parking, so the complexity of parking purpose intensify "parking problem". However, Chongqing Tumor Hospital adopts the management measures restricting the parking of cars for commuting, and the parking spaces are mainly used for visiting patients, thus simplify the composition of parking purpose and improve the operation efficiency.

2.1.3. The Length of Parking Time

The corresponding parameters of the length of parking time with the turnover rate determine the service efficiency of parking garage. The length of parking time is related with parking purpose and management mode. Among the investigated hospitals, only Southwest Hospital doesn't charge parking fee. The First Affiliated Hospital of Chongqing Medical University has nearly grade and scale with Southwest Hospital, but it charges. So it is chosen to compare and analyze.

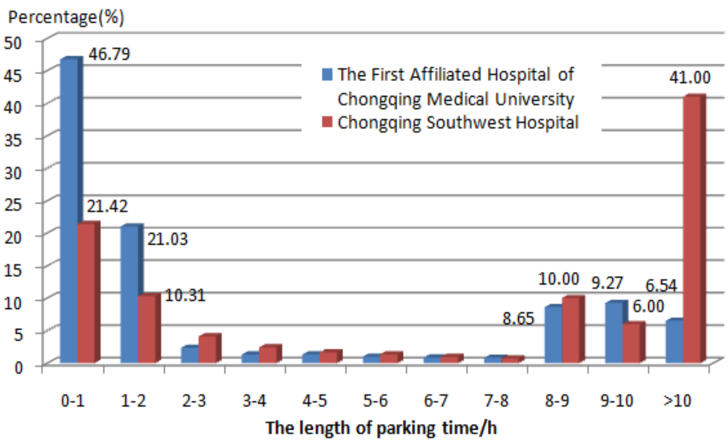


Figure 4. Parking Duration of Hospital

Figure 4 shows that: The length of parking time has "two obvious extremes", one is short-time parking (1~2h) with high turnover rate for hospitalizing and visiting, the other one is longtime parking (>8h) of medical staff for commuting. By comparing the datum of Southwest Hospital and the First Affiliated Hospital of Chongqing Medical University, it is clear that: the longtime parking cars (>8h) of Southwest Hospital counts 57%. The longtime parking car occupies parking space, and it affects the normal order of hospital parking seriously. The First Affiliated Hospital of Chongqing Medical University adopts management measures of charging parking fee, so the short-time parking cars (1~2h) counts 67.82%, and longtime parking cars (>8h) only counts 24.46%.

Therefore, according to Figure 3 and Figure 4 it is clear that： Parking management policy has a great influence on hospital parking character and car drivers' parking behavior.

2.1.4. Walking Distance after Parking

Walking distance after parking is a notable factor influencing car driver's parking choice, and the average walking distance for different parking purposes is as shown in Figure 5.

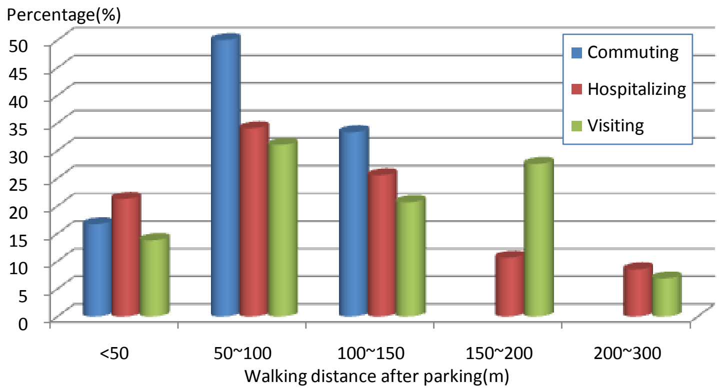


Figure 5. Walking Distance of Different Purpose after Parking in Hospital

Among these parking purposes, drivers for hospitalizing have higher requirements on walking distance after parking. If they couldn't find a parking space for a long time, the probability of illegal parking will increase in the case of tension and anxiety. However, drivers for commuting have lower requirements on walking distance after parking. Figure 5 shows that: At present, most hospitals adopt extensive parking management modes. All the investigated hospitals haven't implemented divisional parking, and it leads to that the walking distance about 66.67% staffs is less than 100m. However, for patients and visitors who have higher requirements on convenience, the proportion that the walking distance is more than 100m is 44.68% and 55.17% respectively. Hospital staffs are familiar with the layout of hospital, so the convenient parking spaces are occupied by them for a long time. That not only causes inconvenience for hospitalizing and visiting, but also reduces the efficiency of hospital parking garage.

2.2. The Influence Factors of Parking Mode Choice

The hospital parking modes mainly include these types: centralized plane garage, curb parking, stereo parking garage (include self-propelled and Mechanical parking garage). There are many factors influencing car drivers' parking choice, except for manifest variables (such as gender, parking purpose, vehicle price and driving years), there should also include the subject, uncertain factors of perception and attitude, namely latent variables.

The introduction of latent variables makes it possible to study parking mode choice behavior from the mental perspective of car driver [11]. The biggest difference between latent variables and manifest variables is that: latent variable is a kind of variable that can't be statistical measured directly; usually it needs other manifest variables (observable variables) to measure. The latent variable of hospital parking like convenient level can't be measured directly, but it can be measured by other observable variables like walking distance, satisfaction level with parking guidance facilities and unobstructed level on entrances and exits. For another example, the comfort of parking in hospital is a latent variable which is judged by car drivers' feelings, and it can be measured by observable variables like the size of parking space, whether the traffic lanes are clear and the overall feelings about parking environment. These observable variables can be measured by objective indicator like Likert scale.

Aiming at hospital parking mode choice behavior, generally the sets of choice mode include: centralized plane garage, curb parking, stereo parking garage. The contained manifest variables, latent variables and observables is shown in Table 1, latent variables are described by the observable variables of latent variables, and the observable variables are measured by Likert scale5.

Table 1. Characteristic Variables of Hospital Parking Mode Choice Behavior

Category	Characteristic Variables		Observable Variables
Drivers Manifest Variables	Gender	GE	Male=1 Female=2
	Parking Purpose	PU	Visiting=1、Hospitalizing=2、Commuting=3
	Driving Experience	DE	<1year、1~6year、6~10year、10~20year、＞20 years
	Car Price	CP	<50thousand、50-100thousand、100~200thousand、200-300thousand、＞ 300thousand
Latent Variables	Parking Convenience	PN	PN1：Walking Distance after Parking
			PN2：Satisfaction Level with Parking Guidance Facilities
			PN3：Unobstructed Level on Entrances and Exits
	Parking Feeling	PF	PF1：Deposit/Take out Vehicle Time
			PF2：The Expected Close Degree with Deposit/Take out Vehicle Time
			PF3：Whether Have Multimedia Information in Deposit/Take out Vehicle
	Parking Comfort	PC	PC1：Whether Parking Lot Size is Fit
			PC2：Whether Traffic is Clear
			PC3：Parking Environment Perception
	Parking Safety	PS	PS1：Watching Situation of Managers
			PS2：The Set of Pedestrian Passageway
			PS3：Parking Safety Facilities
	Parking Service Environment	PE	PE1：Air Condition of Parking
			PE2：Administrators Service Attitude
			PE3：The Order of Parking

3. The Establishment of SEM-ML Integration Model

There may be involved with many measured variables in the course of studying hospital parking mode choice behavior, and that turns the course into a complex hierarchical structure with many reasons and results. So we can’t use the traditional regression analysis method to explain the relation between latent variables and latent variables, measured variables and latent variables. Structural equation model (SEM)—A multivariate data statistic model which is widely used in management science and psychology can deal with these problems well, but it is rarely applied into transportation at present and not parking behavior yet [12]. Therefore, this paper will integrate structural equation model and the ML model to establish SEM-ML integration model, and use it to study hospital parking behavior.

3.1. Model Assumption

The assumed conditions of SEM-ML integration model are as follows:

① Drivers will choose the optimal parking mode in the hospital;

② Taking centralized plane garage, curb parking and stereo parking garage(include self-propelled and Mechanical parking garage) as parking mode choice results, also it could cluster and refine by the practical parking mode in the hospital. This wouldn't influence the calculation method and content of model;

③ On the basis of random utility theory, the parking mode choices of drivers depend on utility function (U) containing manifest verities and latent variables;

④Among the stochastic error terms, utility function is Gumbel distribution, and the others is normal distribution.

3.2. Establishing SEM-ML Integration Model

The establishment of SEM-ML integration model is fully considered the influence of manifest variables and latent variables on hospital parking mode choice. According to SEM, it describes the route and causal relationship between latent variables and manifest variables, latent variables and observable variables. It reflects the mechanism of parking mode choice, according to ML model, describe non-Linear function relationship between the probability of certain parking mode choice and select manifest variables and latent variables. The structure chart of SEM-ML integration model is shown in Figure 6.

According to random utility theory, drivers pursue the maximum of "Utility" when choosing parking mode. Let us assume that the set of parking mode chosen by driver is A_n, and take U_{in} in Eq. (1) as utility of the ith parking mode chosen by the nth driver.

$$U_{in} = V_{in} + \varepsilon_{in} \tag{1}$$

In Eq. (1): V_{in} is the fixed term in utility function of the ith scheme chosen by the nth driver, ε_{in} is the probability item, and assume that variables contained by V_{in} are linear relation.

$$V_{in} = \sum_{k=1}^{K} \theta_k X_{ink}, (i \in A_n) \tag{2}$$

In Eq. (2): $\theta = (\theta_1, \cdots \theta_k)$ is unknown parameter vector, $X_{ink} = (X_{in1}, \cdots X_{ink}, \cdots, X_{inK})$ is influence factor vector of the ith scheme chosen by the nth driver. To make that utility function could both contain manifest variables like alternative scheme, drivers' character, and mental latent variables like drivers' attitude, perception, we amend V_{in} as:

$$V_{in} = \sum_{m} \theta_{im}^{'} p_{imn} + \sum_{q} \theta_{iq}^{'} d_{iqn} + \sum_{l} \theta_{il}^{'} \eta_{i\ln} \tag{3}$$

In Eq. (3): m is the number of manifest variables in alternative scheme, q is the number of driver's manifest variables, l is the number of latent variables, p_{imn} is the manifest variables in alternative scheme, d_{iqn} is car drivers' manifest variables , η_{iln} is latent variables, $\theta_{im}^{'}$, $\theta_{iq}^{'}$ and $\theta_{il}^{'}$ are unknown parameters.

The fitted relation of latent variables η_{iln} is determined by SEM, η_{iln} can be expressed by related manifest variable y_{irn} in Eq. (4) or its corresponding measurement index x_{itn} in Eq. (5).

$$\eta_{i\ln} = \sum_{t} \alpha_{i\ln} y_{itn} + \delta_{i\ln} \tag{4}$$

$$x_{i,r,n} = \sum_{l} \beta_{ilr} \eta_{iln} + \zeta_{irn} \tag{5}$$

In Eq. (4) and Eq. (5): y_{itn} is the related manifest variable of latent variable, $\alpha_{i\ln}$ is the parameter to be estimated, $x_{i,r,n}$ are a series of measured variables corresponding to latent variables, $\delta_{i\ln}$, ζ_{irn} are errors-in-variable, t is the number of manifest variables related with latent variables. r is the number of measured variable corresponding to latent variables.

U_{in} and U_{jn} are the utility of alternative scheme i and j of drivers, introducing two-valued variable D_{in} to describe parking mode choice decision behavior.

$$
\begin{aligned}
& if\,(U_{in} \geq U_{jn}, \forall i, j \in A_n) \\
& \qquad D_{in} = 1; \\
& else \\
& \qquad D_{in} = 0;
\end{aligned} \tag{6}
$$

According to random utility theory, combined with Eq. (3) and Eq. (6), derive the probability of the nth driver choosing the ith parking mode in SEM-ML model in the case of considering latent variables.

$$
\begin{aligned}
P_{in} &= \mathrm{Prob}(\mathrm{U}_{in} > \mathrm{U}_{jn}; i \neq j, i, j \in A_n) \\
&= \mathrm{Prob}(\mathrm{V}_{in} + \varepsilon_{in} > \mathrm{V}_{jn} + \varepsilon_{jn}; i \neq j, i, j \in A_n) \\
& 0 \leq P_{in} \leq 1, \sum_{i \in A_n} P_{in} = 1
\end{aligned} \tag{7}
$$

On the basis of theory of utility maximization, the selection of alternative scheme i refers to that U_{in} exceeds the maximum utility $\max U_{jn}$ of j schemes in A_n .

$$
\begin{aligned}
P_{in} &= \mathrm{Prob}(\mathrm{U}_{in} > \max \mathrm{U}_{jn}; i \neq j, i, j \in A_n) \\
&= \mathrm{Prob}(\mathrm{V}_{in} + \varepsilon_{in} > \max(\mathrm{V}_{jn} + \varepsilon_{jn}); i \neq j, i, j \in A_n) \\
&= \mathrm{Prob}\left[\left(\sum_m \theta'_{im} p_{imn} + \sum_q \theta'_{iq} d_{iqn} + \sum_l \theta'_{il} \eta_{i\ln}\right) + \varepsilon_{in}\right. \\
&\quad \left. > \max\left[\left(\sum_m \theta'_{jm} p_{jmn} + \sum_q \theta'_{jq} d_{jqn} + \sum_l \theta'_{jl} \eta_{j\ln}\right) + \varepsilon_{jn}\right]\right] \\
&\qquad (i \neq j, i, j \in A_n)
\end{aligned} \tag{8}
$$

On the basis of probability theory, selective probability P_{in} of alternative scheme i is deduced further when random error term ε_{in} is Gumbel distribution.

$$
P_{in} = \frac{\exp\left(\sum_m \theta'_{im} p_{imn} + \sum_q \theta'_{iq} d_{iqn} + \sum_l \theta'_{il} \eta_{i\ln}\right)}{\sum_{j \in A_n} \exp\left(\sum_m \theta'_{jm} p_{jmn} + \sum_q \theta'_{jq} d_{jqn} + \sum_l \theta'_{jl} \eta_{j\ln}\right)} \tag{9}
$$

Further, P_{in} is deduced and simplified into:

$$
\begin{aligned}
P_{in} &= \frac{\exp\left(\sum_m \theta'_{im} p_{imn} + \sum_q \theta'_{iq} d_{iqn} + \sum_l \theta'_{il} \eta_{i\ln}\right)}{\exp\left(\sum_m \theta'_{im} p_{imn} + \sum_q \theta'_{iq} d_{iqn} + \sum_l \theta'_{il} \eta_{i\ln}\right) + \exp\left(\sum_m \theta'_{jm} p_{jmn} + \sum_q \theta'_{jq} d_{jqn} + \sum_l \theta'_{jl} \eta_{j\ln}\right)} \\
&= \frac{1}{1 + \exp\left[\left(\sum_m \theta'_{jm} p_{jmn} + \sum_q \theta'_{jq} d_{jqn} + \sum_l \theta'_{jl} \eta_{j\ln}\right) - \left(\sum_m \theta'_{im} p_{imn} + \sum_q \theta'_{iq} d_{iqn} + \sum_l \theta'_{il} \eta_{i\ln}\right)\right]}
\end{aligned} \tag{10}
$$

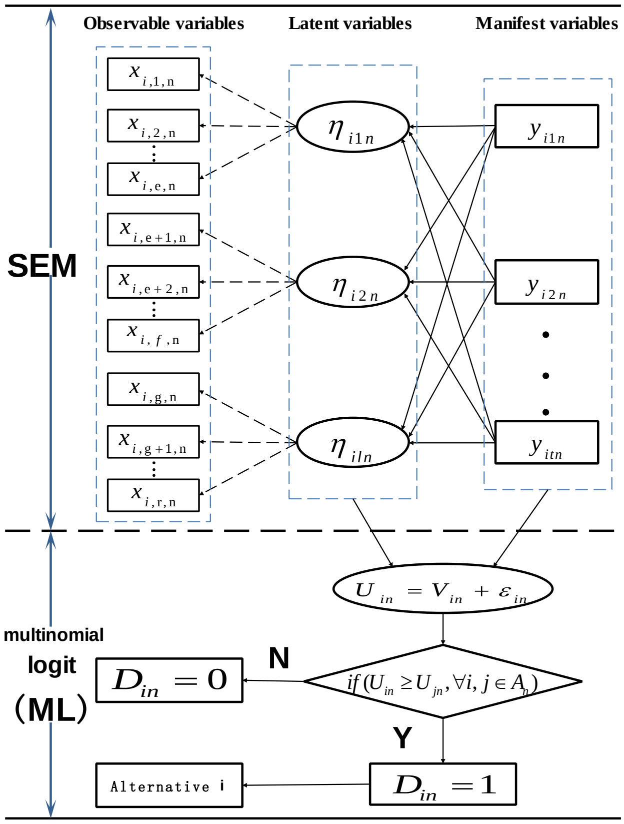


Figure 6. SEM-ML Integration Model Flow Chart

3.3. Data Collection and Model Solution

To fit unknown parameters in the SEM-ML integration model, designing investigation questionnaires and collecting samples on the basis of actual research. Researches show that: The sample size of SEM model $N \geq 100$; when $N = 100$, each divisor needs four target variable [13], $N \in [200 \sim 500]$ is the best sample range, standard sample size should be 10-15 times as big as the number of variables.

Adopting AMOS and SPSS software to solve the model, the solving steps as follows.

① Data input: Input the obtained original data into SPSS software.

② Solve the fitted value of latent variables in SEM: Import the original data of SPSS into AMOS, and construct SEM-ML mode choice model among manifest variables, latent variables and observable variables according to Eq. (4) and Eq. (5).

③ Solve variation coefficient of ML: Substitute manifest variable value which has influence on the results of choice and the fitted value of latent variable obtained by last step into ML model, solve each variation coefficient by SPSS software.

④ Model evaluation and checking: The common checkout parameters of ML model include: Wald Chi-squared test, t-test, Pseudo R^2-test (Cox and Snell, Nagelkerke, McFadden).

4. Case Analysis

This study defines the set of hospital parking mode choice (A_n), manifests variables of drivers' characters (gender, parking purpose, driving experience and vehicle price) and latent variables (convenient level, the feelings and comfort of parking, safety, service environment), as is shown in Table 1. Latent variables are described by measured variables and measured by Likert scale5. Drivers of Southwest Hospital (Grade III-A Hospitals) are taken as respondents, we carry out a face-to-face investigation on parking behavior, 366 questionnaires in tall. Screen out unqualified questionnaires with halfhearted answers, 6 or more continuous extreme answers and 3 or more missing answers. At last 316 valid questionnaires are obtained, the effective rate is 86.34%.

To assess the application effect of SEM-ML model considering latent variables, firstly analyze the five latent variables affecting hospital parking choice behavior to confirm that the chosen latent variables and its observed variables are valid or not. On this basis, compare and analyze the effectiveness evaluation and explanatory ability between SEM-ML and ML model.

4.1. Effectiveness Test of Latent Variables and Observed Variables

Because of lacking evaluation indexes of hospital parking choice behavior and the feeling of parking, combined with case study we need to verify that whether latent variables and observed variables are valid. This paper extracts the latent variables (convenient level, the feelings and comfort of parking, safety, service environment) whose eigenvalues are greater than 1 by applying PCA (principal component analysis). The rotated load matrix is shown in Table 2.

Table 2 shows that: The selected five parameters (α) of latent variables are all greater than 0.69 and the confidence level is relatively high. The load of selected factors are all greater than 0.5, namely the measured variables of selected latent variables are all valid.

Table 2. Rotated Loading Matrix of Latent Variable

Latent Variables	Observable Variables	PN	PF	PC	PS	PE
PN	PN1	0.885	0.163	0.052	-0.027	-0.035
	PN2	0.780	0.141	0.032	0.182	0.352
	PN3	0.702	0.477	0.251	0.014	0.115
PF	PF1	0.224	0.729	0.151	0.014	0.245
	PF2	0.072	0.705	0.179	0.141	0.276
	PF3	0.011	0.695	0.055	0.488	0.438
PC	PC1	0.139	0.021	0.859	0.068	0.203
	PC2	0.392	0.437	0.790	0.007	0.116
	PC3	0.314	0.496	0.701	0.361	0.012
PS	PS1	0.096	0.110	0.029	0.925	0.064
	PS2	0.049	0.039	0.043	0.924	0.072
	PS3	0.283	0.115	0.075	0.874	0.090
PE	PE1	0.213	0.299	0.002	0.207	0.843
	PE2	0.290	0.148	0.051	0.077	0.758
	PE3	0.093	-0.023	0.163	0.147	-0.716

4.2. Comparative Evaluations of Effect between Traditional ML Model and SEM – ML Integration Model

4.2.1. Traditional ML Model

At first, only consider the influence of drivers' manifest variables on parking mode choice, substitute manifest variables into traditional ML model, and establish hospital parking mode choice model without regard to latent variables. Applying

SPSS software and procedure to estimate and examine parameters, the results are shown in Table 3.

Wald chi-squared statistics which are used to examine the significance level of Logistic regression coefficient are approximate chi-square distribution whose degree of freedom is equal to the number of parameters; a big Wald chi-square statistical magnitude indicates that this parameter has a greater influence on choice behavior. The coefficients of GE and CP in Table 3 are negative, positive PU and DE indicate that female driver's possibility of choosing hospital stereo parking garage is lower than that of male driver's; The higher the driver's vehicle prices is, the lower the possibility of choosing hospital stereo parking garage is; but drivers for commuting or drivers with long-time driving years tend to choose stereo parking garage.

4.2.2. SEM-ML Integration Model

There exist different describing methods between latent variables and observed variables. Therefore, we substitute the five latent variables of hospital parking choice behavior into SEM-ML integration model. It can establish different integration model.

① SEM-ML1 integration model: Substitute all measured variables into integration model (Table 2), and describe the relationship between observed variables and latent variables by factor analysis.

② SEM-ML2 integration model: The variable with maximal factor load is used to describe the relationship between observed variables and latent variables by factor analysis.

③ SEM-ML3 integration model: Use structural equation to describe the relationship among manifest variables, latent variables and observed variables [Eq. (4) & Eq. (5)], the results are shown in Table 3.

Table 3. Results of Traditional ML Model and SEM-ML Model

Model	Project	Constant	GE	PU	DE	CP	PN	PF	PC	PS	PE
M L	α	-3.85	-0.16	0.78	0.51	-0.24	-	-	-	-	-
	Wald	26.52	9.84	39.93	47.84	2.37	-	-	-	-	-
SEM-ML1	α	-6.89	-0.49	0.81	0.49	-0.31	0.55	0.67	0.44	0.46	0.43
	Wald	19.76	6.02	36.10	40.57	1.77	15.09	9.68	7.08	4.83	2.97
SEM-ML2	α	-6.71	-0.49	0.89	0.510	-0.29	0.57	0.78	0.49	0.37	0.29
	Wald	20.58	6.83	38.29	42.79	1.59	15.89	8.01	7.26	4.01	2.18
SEM-ML3	α	-6.20	-0.47	0.97	0.45	-0.27	0.88	0.44	0.51	0.59	0.32
	Wald	17.61	5.10	33.26	39.68	1.04	16.57	7.69	8.35	4.22	2.36

4.2.3. The Check Result of Traditional ML Model and SEM-ML Model

The check result of traditional ML model and SEM-ML model is shown in Table 4.

Table 4. Evaluation of the Traditional ML Model and SEM-ML Model

Model	Pseudo R^2-test		
	Cox & Snell	Nagelkerke	McFadden
ML	0.751	0.846	0.635
SEM-ML1	0.777	0.787	0.855
SEM-ML2	0.721	0.754	0.819
SEM-ML3	0.788	0.896	0.903

The range of the three evaluation indexes in Pseudo R^2 test is between 0 and 1, and the closer it is to 1, the higher the accuracy of model is. Table 4 shows that: Each checking index of SEM-ML integration model is superior to ML model. Cox & Snell checking value is increased from 0.751 to 0.788, Nagelkerke checking value is increased from 0.846 to 0.896, McFadden checking value is increased from 0.635 to 0.903, which shows that integration model has a better explanatory ability than traditional model, latent variables of driver have a great influence on parking mode choice. After considering latent variables, the constant term-Wald value decreases obviously, this shows that there exists missing variables in ML mode. Taking PU (parking purpose) as an example, the influence of parking purpose on hospital parking mode choice increases obviously in SEM-ML model, it shows that the influence of parking purpose on parking mode choice is underestimated in traditional ML model.

According to the contrastive analysis of SEM-ML1/2/3 model, in SEM-ML1/2 model, the parking feelings (PF) impact the results of choice most and the service environment's (PE) influence is minimal. In SEM-ML3 model, the convenient level (PN) impacts the results of choice most and the service environment's (PE) influence is minimal. The reason for the difference is that: The fitted value of latent variables is obtained by factor analysis in SEM-ML1/2, neglecting the influence of manifest variables on drivers' latent variables. This leads to a deviation of estimate value of parameter, decreasing the accuracy and explanatory ability of model. Meanwhile, the establishment of SEM-ML2 model only substitute measured variables with big load matrix, but the establishment of SEM-ML1 model substitute all measured variables. And the value of Pseudo R^2 test in SEM-ML2 model is less than that in SEM-ML1. That shows that only substituting measured variables with big load matrix will lead to loss of information when modeling. In conclusion, SEM-ML3 integration model which describes the relationship between latent variables and manifest variables, latent variables and observed variables has a higher accuracy and a better explanatory ability.

4.3. Analyzing the Structural Pattern and Measurement Pattern of SEM-ML Integration Model

SEM-ML integration model of hospital parking mode choice behavior is further analyzed by AMOS software, and divides the model into two parts:

4.3.1. Structural Pattern:

Describing the relationship between latent variables and manifest variables of driver's characters.

Structural pattern shows that: The influence of driver's gender on convenient level and service environment is positive correlation. It shows that the demands of female drivers on convenience and service environment are higher than that of male drivers; the influence of parking purpose on the feelings of parking is negative correlation. It shows that driver for hospitalizing and visiting attach more attach importance to the feelings of parking; the influence of driving years on comfort is negative correlation, it shows that drivers with short driving years care more about comfort for the limitation of technological level; the influence of parking purpose and vehicle price on safety is positive correlation, it shows that drivers for commuting and drivers whose vehicle price is high care more about safety.

4.3.2. Measurement Pattern:

Describing the relationship between latent variables and manifest variables.

Measurement pattern shows that: To the convenience of hospital parking, the indexes that drivers care most are the unobstructed level on entrances and exits (PN3) and satisfaction of parking guidance facilities (PN2); to the feelings of parking, the indexes that drivers care most are the proximity of parking time to expectation (PF2) and whether there is multimedia information when parking; as for the comfort of parking, the indexes that drivers care most are whether the size of parking space is suitable (PC1) and whether the traffic lanes are clear (PC2); To the safety of parking, the indexes that drivers care most are the watching situation of managers (PS1) and the set of pedestrian passageway (PS2); to the service environment of parking, the indexes that drivers care most are the order of parking (PE3) and air conditions in parking garage (PE1). The above research conclusions provide the basis and inspiration for hospitals to make strategies for relieving parking problem from the mental perspective of drivers, and also for planning, site-selection and equipment-selection of adding parking facilities.

Table 5. Structural Equation Model Results of Hospital Parking Mode Choice Behavior

Pattern	Variable	Parking Convenience（PN）		Parking Feeling（PF）		Parking Comfort（PC）		Parking Safety（PS）		Parking Service Environment（PE）		Standard Deviation of The Error Term	
		Parameter	Wald Value	Parameter	Wald Value	Parameter	Wald Value	Parameter	Wald Value	Parameter	Wald Value	Parameter	Wald Value
Structural Pattern	Gender	0.09	7.34	—	—	—	—	—	—	0.11	4.34	0.21	7.52
	Parking Purpose	—	—	-0.28	8.56	—	—	0.10	5.68	—	—	1.94	7.57
	Driving Experience	—	—	—	—	-0.198	2.31	—	—	—	—	0.40	7.04
	Car Price	—	—	—	—	—	—	0.15	4.88	—	—	1.82	7.27
Measurement Pattern	PN1	0.56	4.32	—	—	—	—	—	—	—	—	1.24	6.82
	PN2	0.62	4.54	—	—	—	—	—	—	—	—	0.98	6.24
	PN3	0.67	5.66	—	—	—	—	—	—	—	—	1.52	6.98
	PF1	—	—	0.61	7.03	—	—	—	—	—	—	1.26	5.28
	PF2	—	—	0.83	8.76	—	—	—	—	—	—	1.33	4.24
	PF3	—	—	0.79	7.24	—	—	—	—	—	—	0.54	5.35
	PC1	—	—	—	—	0.72	5.46	—	—	—	—	0.79	6.23
	PC2	—	—	—	—	0.54	5.23	—	—	—	—	1.07	3.97
	PC3	—	—	—	—	0.31	3.08	—	—	—	—	2.49	7.34
	PS1	—	—	—	—	—	—	0.63	4.74	—	—	1.29	6.98
	PS2	—	—	—	—	—	—	0.53	3.08	—	—	0.97	7.23
	PS3	—	—	—	—	—	—	0.49	2.99	—	—	1.26	3.32
	PE1	—	—	—	—	—	—	—	—	0.71	6.86	0.68	7.53
	PE2	—	—	—	—	—	—	—	—	0.48	6.05	1.17	8.02
	PE3	—	—	—	—	—	—	—	—	0.77	7.62	0.74	6.48

5. Concluding Remarks

Parking mode choice behavior is the basis of developing strategies for relieving parking problem and determining the location and type of newly-increased parking facility. Aiming at the hot issue of parking problem in hospital, firstly, this paper analyzes hospital parking characters, the result shows that: The demand of parking in hospital is highest on Monday, lowest on Friday and steady on weekends. Besides, parking management policy has a great influence on hospital parking character and driver's parking behavior. Then, this paper puts forward latent variables of hospital parking mode choice, establishes three kinds of SEM-ML integration model which could describe characteristic manifest variables and mental latent variables of drivers, analyzes the idea for solving the model and applies it to the example analysis. The result shows that: SEM-ML model is more in accordance with practical parking choice process than ML model, and it has higher accuracy and better explanatory ability. Among the three integration models, SEM-ML3 integration model has higher accuracy and better explanatory ability.

Besides, from the perspective of quantification, the research results verify that manifest variables (parking purpose) and mental latent variables (convenient level and parking feelings) have influence on parking mode choice, and drivers focus on the feelings parking. Therefore, in the construction and management of parking garages, hospitals should stick to the following three principles: Firstly, the principle of convenient parking. Among all kinds of parking purposes, drivers for hospitalizing and visiting demand higher convenience than medical workers whose purpose is commuting. So hospital should implement function division management for parking. Convenient parking spaces give priority to short-time and high-velocity parking demand for hospitalizing and visiting. This could improve the efficiency of whole parking system; besides, parking planning should focus on keeping the entrances and exits and exits unobstructed and improving the parking guidance facilities; Secondly, the principle of comfortable parking. Drivers are more concerned about the feelings of parking, so hospital should consider the selection of parking equipment and dimensions, and planning parking lanes reasonably. And try to choose the parking equipment whose parking time is close to driver's expectation, and divert driver's attention from parking to multimedia information; Thirdly, principle of safe parking. Long-time-parking drivers for commuting and drivers whose vehicle prices is high care more about the safety, and drivers have more attention on the watching situation and pedestrian passageway. So, on the basis of carrying out managing parking divisionally, hospitals should pay attention to separation of pedestrians and vehicles, and reasonably set soft environment like pedestrian passageway, this could meet the demands of drivers better and increase the efficiency of hospital parking system. Besides, the integration model established by this paper has certain portability. The application and effect in other areas of traffic behavior need further study.

Acknowledgments

Thanks for International Journal of Control and Automation provides the research platform for this study and comments from the reviewers, which greatly help improving this paper. This research is financially supported by National Natural Science Foundation of China (E080701) and Municipal Technology Plan of Chongqing (2013-11).

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