The Value of Travel Time Savings and the High Speed Rail in China

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Abstract

This paper theoretically examines the essence of the value of travel time savings. Some theories of the value of time are reviewed, and some assumptions in these models are rechecked and altered. Then a general time allocation model is proposed, which can give some new explanation of the value of travel time savings. Based on the theoretical model, the problems of large scale construction of high speed rails in China are analyzed.

Keywords: Value of time; Value of travel time savings; high speed rail

Because there is no space or time dimension in neoclassical economic theory, it could not provide a theoretical framework to analyze people's behavior in travel. It is widely accepted thought that travel is induced demand, and reduction of traveling time could increase consumer's benefit. Therefore, reducing traveling time is often an important consideration of investment of transport infrastructure. But there are costs of increasing the speed standard of any kind of transport facilities, and also the costs of its operation. How individuals balance the benefits and costs of reduction in travel times is a key parameter in determining customer's choice among different transport modes. And how individuals evaluate the value of travel time savings (VTTS) is also a critical parameter in transport projects appraisals and in its speed standard deciding. This is especially important for rail industry, which need huge investment in rail infrastructures, such as high speed rail.

China began high speed rail (HSR) construction in 2004, in less than 8 years China has built nearly the similar length HSR as both Japan and Europe had built in half century. From 1964 to 2010, the total length of the HSR built in Japan and Europe is 7700km. While in China, to the end of 2012 there are 8614km high speed lines (running speed above 250km/h) in operation. According to the adjusted railway medium and long term planning in 2008, China would build 16,000 kilometers dedicated passenger high speed lines before 2020.

HSR is rail systems which are designed for a maximum speed in excess of 250 km/h according to the definition of UIC. The first HSR in the world, Japanese Tokaido Shinkansen，started running between Tokyo and Osaka in October 1964, was an immediate success. The success of the Japanese high speed system, particularly in

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gaining market share from air, was undoubtedly a major factor inspiring European railways to follow the same path. While except the Tokaido Shinkansen's revenue could cover its interest and depreciation from its third year operation, other lines in the world contribute very little towards their capital recovery. In China, all of the high speed lines in operation do not reach breakeven, the revenue of Zhengzhou-Xi'an high speed rail can not even cover its interest.

The most obvious benefit of HSR is that it saves time for its users. The revenue of HSR depends on the value it can bring for users. But how individual evaluate the value of time (VOT)? What is VTTS of transport means at different speed especially in a country with large territory? The focus of this paper is on the special nature of VTTS, which may have different characteristic at short distance travel and long distance travel. First, some models of time allocation are reviewed to clarify the concept of VOT and VTTS, and assumptions in these models are rechecked. Second, a time allocation model for the general mode choice behavior is proposed. According to the time allocation model, the special nature of VTTS is presented. Thirdly, with this time allocation model, the problem of HSR construction in China can be revealed. It is not the faster the better, the large scale and high standard construction of HSR will become a serious drag on economic development to China[3].

1. Review of time allocation model

Neoclassical consumer choice theory is not designed to deal with the human behavior with either time or space dimensions. Its utility model only consider goods and income constraint, the time factor was not included in its theoretical models because time was viewed as assigned to work to earn money, not as an input of consumption. To economics theory the challenge is that time resource has some different characteristics from economic resources in markets, time factor is too "slippery" to handle. Then how to introduce time dimension into economics model, which must be consistent with individuals' attitudes towards time and the special characteristics of time, is the key issue in the theoretical model of time allocation.

Becker (1965) made the first attempt to develop a general treatment of the allocation of time in all non-work activities. His approach just follows the neoclassical technique. Specifying a utility function and constraints including time factor, then constructing a Lagrangian function and basing on equilibrium conditions, the conditions of optimal time allocation can be derived out. This research line is followed by other economists in time allocation study, and the further development in model construction is only on what variables should be included in utility function and how to specify the constraints.

Becker thought individuals consume goods must spend time, so what individual

[3] This opinion of Zhao Jian had been cited not only by Chinese media but by *The New York Times*, the *Washington Post*, *Time* magazine and the *Financial Times*.

consumed is basic commodities or final goods, which include goods and time as inputs. Basic commodities can write as Z_i, $Z_i = f_i(x_i, T_i)$; i=1,……, m; where x_i is a market goods, T_i is the time used to consume the market goods x_i.

Individuals have to combine time and market goods to produce more basic commodities that directly enter their utility functions. Becker specify utility function as $U = U(Z_1, Z_2, ..., Z_m) \equiv U(f_1, f_2, ..., f_m) \equiv U(x_1, x_2, ..., x_m; T_1, T_2, ..., T_m)$

Becker postulated that there are linear relationship between basic commodity and time as well as market goods, that is $\begin{cases} T_i \equiv t_i Z_i \\ x_i \equiv b_i Z_i \end{cases}$, t_i and b_i are coefficients that convert one unit of basic commodity into necessary time and necessary goods respectively. That means there are a fixed converting relationship between goods and time, T_i are not independent variable， $T_i = \frac{t_i}{b_i} x_i$, time constraint can be converted to goods constraint only the time related parameters t_i being reserved, and the decision variable T_i can not be in the constraint. The income constraint $\sum_1^m p_i x_i = I$ and time constraint $\sum_1^m T_i = T_c = T - T_w$, therefore, can be integrated into one constraint in Becker's model.

In Becker's theory, time could be converted into money by assigning less time to consumption and more time to work. Therefore non-work time could be valued at the same level of the wage rate because consumption has a time cost of not earning money. This is the first concept of wage rate approach of VOT.

Becker first introduce time factor into utility function, while he only considered non-work time. If work time is not in consideration, there would be an incomplete picture of how individuals make choice on time allocation. Becker tried to explain how individuals allocate time in various consumption activities, while it is different from allocation money among various goods. Time has some specific different characteristics. Becker must make some assumptions for explaining this issue. Firstly, he assume that the time used to consume a good is fixed, for example drinking a cup of coffee spend 10 minutes, no longer and no shorter. This strict assumption make Becker could not explain the issue of saving time, which potentially makes it can not define the concept of VTTS. Secondly, Becker assume one period of time can only use for one piece of consumption goods. It is not consistent with common sense, for example see a film and drink a cup of coffee can be at the same time. Some defects of Becker's was improved by Johnson (1966) and DeSerpa (1971).

Contrary to Becker, Johnson argued that work time must be included in utility function, because that work and leisure are distinct variables in time allocation decision. Johnson belief that failure to specify the utility function accurately leads to qualitatively different equilibrium conditions and to specification error. The common thinking that the value of travel time is equal to the wage rate is an example of this specification error. Johnson specified utility function including four choice variables: U = U(X, C, W, L), trips by X, the non-trip composite commodity by C, work time by W, and leisure by L. By introducing the variable of composite commodity, Johnson avoided the problem of some commodity goods can be consumed at the same time.

Johnson also separated the money budget constraint and time budget constraint as two different constraints, which made the time dimension more clearly as an independent constraint in the model. Different specification on utility function and constraints lead to different conclusion, according Johnson's model, the marginal rate of substitution of income for leisure—the value of travel time—must be less than the money wage rate.

While this conclusion maybe contradicts to some other characteristics of time, the value of time can change depending on specific situation. Various qualitative factors such as travel convenience, comfort, and security can also affect the value of travel time. Albert Einstein once illustrated the relativity of time by saying, "When a man sits with a pretty girl for an hour, it seems like a minute. But let him sit on a hot stove for a minute and it's longer than any hour". The value of time spending with a pretty girl must be larger than the money wage rate. The value of time is volatile depending on usage for what and on the specific situation. Johnson's conclusion must come from some wrong specification in his model, especially in his inelastic time constraint, which was later improved by DeSerpa to some extent.

DeSerpa specified the utility function as $U = U(X_1, X_2, ..., X_n; T_1, T_2, ..., T_n)$, which seems similar with Becker's. He also assumed that goods are consumed one at a time and all the time available to the individual is spent in the consumption of some commodity. The two resource constraints, a money constraint and a time constraint, is similar to other economists. What different from his preceding economists was DeSerpa adding n inequalities of time consumption constraints. DeSerpa postulated that the decision to consume a specified amount of any commodity requires that some minimum amount of time to be allocated to it, but the individual may spend more time in that activity if he so desires. The time consumption constraints write as $T_i \geq a_i X_i, \quad i = 1, 2, ..., n$, where a_i is interpreted as a technologically or institutionally determined minimum amount of time required to consume one unit commodity of X_i .

There are n+1 time constraints in DeSerpa's model, one time resource constraint and n time consumption constraints. Based on this specification of these constraints, DeSerpa defined three kinds of VOT. First, the value of time as a resource (VTR) is the marginal rate of substitution between time and money. Second, the value of time as a commodity (VTC) is the value of time allocated to a certain activity. Thirdly, the value of time savings (VTS) is the value of reducing time required to spend in an activity. In the earlier study, value of leisure time and value of travel time was often confused. DeSerpa demonstrated the difference of the two concepts. Leisure was considered activities that individuals would like allocated more time than required, so its VTS is equal to zero. Travel, if it is a derived demand, is considered activities that individual would like allocated less time than required, its VTS is greater than zero. Attributing a positive VTS from any activity presupposes that the time saved can be transferred to some alternative usage of greater value. Therefore VTS is empirically observable. DeSerpa showed that the VTS in an activity is equal to the VTR minus the VTC, that is: $\frac{K_i}{\lambda} = \frac{\mu}{\lambda} - \frac{U_{n+i}}{\lambda}$; $\frac{K_i}{\lambda}$ is the value of saving time from consuming X_i ; $\frac{\mu}{\lambda}$ is the value of time in alternative use, that is the value of time as resource; $\frac{U_{n+i}}{\lambda}$ is the value of time in consuming X_i , U_{n+i} is the partial derivative of the utility function with respect to T_i.

By introducing a series of inequality time constraints, DeSerpa defined the concept of VTS. While in DeSerpa's utility function there are n kinds of consumption goods, n pieces of time allocated to each goods. In his time consumption constraints there are n inequalities. The question is that can the saved time form one commodity consumption can be freely arranged to another activity according to the individual's timetable? What is the value of time if several activities proceeding at the same time? For example, a man sitting with a pretty girl on a train and drinking coffee with the girl together, here three activities, travel, with a pretty girl and consuming coffee are proceeding at the same time.

Jara-Diaz (2003) thought that DeSerpa's time consumption constraints first established direct relations that involve commodity and time. Which implied that X_i acted like a single composite good (e.g. sport garments), associated with an activity i (a soccer game) whose duration was (90 minutes). Then the original denomination for "consumption time" turned into "activity". Thus DeSerpa's time consumption constraints say that an activity has a minimum duration depending on the amount of goods consumed. Jara-Diaz emphasized the importance of establishing the technological relations between goods consumption and time assigned to activities by DeSerpa，because identifying clearly these relations was a necessary step to improve our understanding of consumer behavior. While what important in DeSerpa's model is not the technological relations, Becker had established the relation implicitly, but the unequal constraints, from which some new concepts of value of time were derived out.

Small (1982) pointed out that the value of time savings will vary by time of day depending on the interaction between scheduling considerations and time-varying price or service quality, that a shift in the timing of an activity involves tangible and measurable welfare effects. By adding scheduling considerations to both the utility function and the constraints, Small included four variables in his utility function, a numeraire good x, leisure time l, working time h and schedule s, U = U (x, l, h, s). For work trip, s could be the time the trip begun, if the trip time is within a fixed peak period, or at which time a particular congested area will be entered, the welfare level would be greatly reduced.

Of course scheduling choice is one of many factors which influence the value of time savings. However, schedule is difficult to deal with in a model, because it is a specific time in a day which is not a continuous variable. Maximizing utility function should derive partial derivatives of the four variables in Small's utility function. For leisure time and working time, they are continuous variables, their partial derivative have some economic meaning. While schedule is an incontinuous variable, the partial derivative of schedule time has no any meaning. According to the schedule, arriving a minute earlier before the departure time of an airplane or a train, you can catch the airplane or the train, and a minute later you cannot catch it. The value of time to catching an airplane or a train would be much higher than wage rate, any price you would like to pay if you are attending an important appointment. What Small emphasized is the value of time savings is volatile, but not a constant. The question is that can this factor such as schedule is expressed in another and meaningful way?

In summary, there are two basic assumptions in the existing theoretical models on the value of time which are not consistent with reality. One is the assumption that a certain amount of time is assigned to only one activity or only consuming one commodity. For an individual, all the time is allocated to four basic activities: working, travel, sleeping, leisure and consumption. Some of these basic activities can take place at the same time. For example, taking a night train by a couchette can both travel and sleeping, taking a sightseeing train can both travel and enjoying beautiful landscape.

Another is the assumption that the value of time is a constant, while the value of time is volatile depending on using for what and in what situation, sometimes the value of time savings even can be negative.

In our time allocation model, we have opposite assumptions. First, a certain amount of time can be assigned to more than one activity. Second, the value of time is not a constant but depending on the individual's preference. For analyzing human behavior in long distance travel, the assumptions must be consistent with real world, and then the specific attributes of VTTS can be evaluated.

2. A time allocation model

Decision making in medium and long distance travel should make transport mode choice and scheduling choice (start and arrival time). For the question discussed is travel between cities, the travel distance is 100 to 2000 kilometers within a country. The transport mode choice is among airplane, high speed train，conventional train, car and bus, other transport mode would spend too much time to outside consideration. The price of different transport modes varies depending on its speed, generally the faster the speed the higher the ticket price. The start and arrival time is also a very important consideration, starting at early morning or arriving at midnight is inconvenient to most people. The start and arrival time could be any time in a day, therefore all the activities should be in consideration. The individual utility is composed of goods consumption, and four kinds of activities spending on work, travel, sleep, leisure and consumption at non work time.

According to these considerations, the following time allocation model is constructed, which takes in some elements of Johnson and DeSerpa's model.

$$\text{Max } U = U(p_x, a_w, a_{i,t}, a_l, a_{j,s}),\ i = a, h, p, c;\quad j = m, h, b \quad (1.1)$$

Where $a_{i,t}$ denotes the time the individual spends in travel that is determined by the choice of transportation mode i, here the first subscript denote transport mode, the second subscript denote travel activity. The travel time $a_{i,t}$ is determined by transport mode choice, airplane $a_{a,t}$, high speed train $a_{h,t}$, conventional passenger train $a_{p,t}$, car or coach $a_{c,t}$. Travel by high speed train can spends less time than conventional passenger train. $a_{j,s}$ denotes the time the individual spends in sleeping which can be at home $a_{m,s}$, hotel $a_{h,s}$, and a berth $a_{b,s}$ in a conventional passenger train. p_x is the cost of composite goods which include durable and non durable goods consumed in various activities. a_w, a_l denote the time the individual spends in the activity of work and leisure.

Because the focus of this model is the problem of time allocation especially in travel, so only one composite good is included in utility function and any time used for all activities in a day is included in, specifically the transport mode should be in consideration. The consumer's attempt to maximize utility is subject to budget constrain and time constraints. The budget constraint is,

$$p_x + r_t(i)a_{i,t} + r_l a_l + r_s(j)a_{j,s} = r_w a_w \qquad (1.2)$$

where $r_t(i)$ is the average price of per unit time for travel by transport mode i, the faster the transport mode the higher the $r_t(i)$, which is proportion to the speed. r_l is the necessary price of per unit time for proceeding related leisure activity, for example it is the average price of per unit time for a movie ticket and the price of coffee consumed during the movie is included in p_x. $r_s(j)$ is the average price of per unit time for sleeping, which related to the input of a bed and house for sleep at home as Becker mentioned (Becker,1965), or which is the average price of per unit time at a hotel, or which is zero because of including in the berth ticket of the train. r_w is wage rate.

The time constraint is $a_w + a_{i,t} + a_l + a_{j,s} = T$ (1.3)

Where T denotes the total time available.

Travel time is determined by transport mode choice. At different travel distance, travelers may have different preference on transport mode choice and take different way to saving travel time, which is indicated by another time constraints:

$$a_{i,t} \geq \bar{t} = \begin{cases} t_{\min} = Min\{a_{a,t}, a_{h,t}, a_{p,t}, a_{c,t}\} \\ t_s \end{cases} \qquad (1.4)$$

Where $t_{\min}$ is the minimum time requirement of a transport mode at a certain distance. t_s is the minimum amount of time required for sleeping, for example 6 hours a day. Constraint (1.4) indicates there are two ways to save travel time in a long distance trip. One is by the fastest transport mode. Another is arranging two activities of sleep and travel at a same time, so the travel time could be saved. If $a_{i,t} \geq t_s$, a traveler can incorporate travel and sleeping together in a long distance trip, for example travel by a conventional train with sleeping cars.

The individual’s efficient allocation of his time and income may be expressed as the maximization of the Lagrange function:

$$L = U + \lambda(r_w a_w - p_x - r_t(i)a_{i,t} - r_l a_l - r_s(j)a_{j,s}) + \mu(T - a_w - a_{i,t} - a_l - a_{j,s}) + k_i(a_{i,t} - \bar{t})$$

(1.5)

The first order conditions are

$$\frac{\partial U}{\partial a_w} = \mu - \lambda r_w \qquad (1.6)$$

$$\frac{\partial U}{\partial p_x} = \lambda \qquad (1.7)$$

$$\frac{\partial U}{\partial a_{i,t}} = \mu + \lambda r_t(i) - k_i \qquad (1.8) \quad \text{either } a_{i,t} = \bar{t} \text{ or } k_i = 0,$$

$$\frac{\partial U}{\partial a_l} = \mu + \lambda r_l \qquad (1.9)$$

$$\frac{\partial U}{\partial a_{j,s}} = \mu + \lambda r_s(j) \qquad (1.10)$$

This equilibrium conditions can reveal some interesting aspects of value of travel time savings. Dividing through (1.8) by λ we get $\frac{k_i}{\lambda} = \frac{\mu}{\lambda} + r_t(i) - \frac{\partial U}{\partial a_{i,t}} \Big/ \lambda$ (1.11)

The ratio μ/λ, according to DeSerpa, was interpreted as the value of time, which is the value of time as a resource. Since μ is expressed in 'utils' per hour and λ in 'utils' per dollar, then the unit of μ/λ is the money value per hour. This explanation was only from a unit analysis, but not from DeSerpa's utility function. So DeSerpa thought μ/λ could not be related to any set of empirical data.

This paper gives an explanation of μ/λ just from the equilibrium condition, which is similar with Johnson (1966). This is just because of the different specification of utility function, we have including work activity in it. From (1.6) we get $\frac{\mu}{\lambda} = r_w + \frac{\partial U}{\partial a_w} \Big/ \lambda$

The value of time, μ/λ is equal to the wage rate plus the marginal value of one more minute work, which can be positive or negative as Johnson pointed. That means the value of time is not a constant, it depends on the situation. In (1.6)， μ/λ or VOT is related with the first order condition of optimal allocation of work time. It may be noted that the first concept of the VOT was the time cost of not earning money, and was equal to wage rate. This is correct only if $\partial U / \partial a_w = 0$. There is no constant value of time, its value is derived from an individual's preference of his work, because working activity can make money to evaluate the value of time. If $\partial U / \partial a_w > 0$, the individual have more utility in his work, his return from working activity is higher than wage rate. If $\partial U / \partial a_w < 0$, the individual have less utility in his work, his return from working activity is lower than wage rate.

According to the DeSerpa's definition, the VTTS is k_i / λ, which is determined by three elements. The first is the VOT or μ / λ which partly related to wage rate, which means the higher the individual's wage rate, the higher his VTTS would be. It is the opportunity value of saved time. μ / λ can be thought as average wage rate, if someone's income level is lower than average, his VTTS by this transport mode would be lower than other people.

The second is $r_t(i)$, which is the cost of choosing transport mode i. This make some economic sense, higher speed often charge higher price. $r_t(i)$ is the cost which must be paid for saving travel time. The choice of the transport mode i means that the individual would like pay its cost. The larger the value of travel time savings, the higher the travel cost would deserve to pay.

The third element is $\frac{\partial U}{\partial a_{i,t}} \Big/ \lambda$, which is the marginal value of additional minute travel time by transportation mode i, which can be positive or negative. If $\partial U / \partial a_{i,t} > 0$, that means increase a minute travel time by transportation mode i can increase the individual's utility. This would be a pleasure travel, the VTTS would decrease. If $\partial U / \partial a_{i,t}$ is so great that $\frac{\partial U}{\partial a_{i,t}} \Big/ \lambda = \frac{\mu}{\lambda} + r_t(i)$, then the VTTS is equal to zero. That means this travel is so easy that the individual would prefer spending more time on it, he does not like to save the travel time.

If $\partial U / \partial a_{i,t} < 0$, that means increase a minute travel time by transportation mode i would decrease the individual's utility. This would be a displeasure trip, the VTTS would increase.

k_i / λ is actually the total value of travel time savings related to a specific transport mode, which is associated with wage rate (i.e., the opportunity cost), which must be able to cover the cost of choosing this transport mode (i.e., the value of cost savings), which is also connected with the traveler's personal preference to the specific transport mode.

What important in equation (1.11) is that it includes the item $\partial U / \partial a_{i,t}$, which reflects the individual's preference on different transport mode choice. Time constraint (1.4) indicates that travelers may have different choice in a long distance travel. A traveler can choose the fastest transport mode, or he can take a slower conventional train with sleeping cars.

For long distance travel, such as more than one thousand kilometer, the individual's preference of time spending on that trip is different during daytime and night.

If travel is on daytime it would be the faster the better, because the time saved can spend on work or leisure. So increasing one minute on travel would reduce an individual's utility, that is $\partial U / \partial a_{i,t} < 0$. The VTTS during daytime is high. The traveler would tend to choose a faster transport mode.

While for a long distance travel, the trip can be arranged at night on a sleeper train, which start in the evening and arrive at next morning, then it is not the faster the better. Arriving to the end at wee hours of the morning the passenger can do nothing in the empty rail station, but interrupt his sleeping. So increasing travel time to arriving at about 7 a.m. may increase an individual's utility, therefore, $\partial U / \partial a_{i,t} > 0$.

Travel at night by a sleeper train, the value of travel time savings equal to zero，i.e., $k_p = 0$, then $\dfrac{\partial U}{\partial a_{p,t}} \Big/ \lambda = \dfrac{\mu}{\lambda} + r_t(p)$. As $\dfrac{\partial U}{\partial a_{p,t}} \Big/ \lambda$ represents the value of time allocated to the activity $a_{p,t}$, $\dfrac{\partial U}{\partial a_{h,s}} \Big/ \lambda$ represents the value of time allocated to the activity $a_{h,s}$ which is the activity of sleeping in a hotel, and $\dfrac{\partial U}{\partial a_{h,s}} \Big/ \lambda = \dfrac{\mu}{\lambda} + r_s(h)$, $r_s(h)$ is the price per hour sleeping in a hotel. Because the two activities travel $a_{p,t}$ and sleeping in a berth $a_{b,s}$ are the same one, what saved are the daytime (not spending in travel) and one night sleeping in a hotel during the trip. So the value of time allocated to travel by a night train is VTTNT,

$$\text{VTTNT} = \frac{\partial U}{\partial a_{p,t}} \Big/ \lambda + \frac{\partial U}{\partial a_{h,s}} \Big/ \lambda = 2\,\mu/\lambda + r_t(p) + r_s(h) \quad (1.12)$$

Though assigning a specific value to any partial derivative of the utility function is not empirically verifiable, equation (1.12) reveal a meaningful qualitative relationship. The value of time allocated to travel by night train is related two times of the opportunity cost of time spending in travel, because of incorporating two activities of travel and sleeping together, and the opportunity cost of stay in a hotel. The value by sleeper train in long distance trip is generally higher than other transport modes.

The two ways of saving travel time in long distance trip seems take totally different mode. One is by a faster transport mode, another is by a slower night sleeper train. The two ways have the same effect on saving travel time. The latter in fact saves almost most travel time by incorporating travel activity with sleeping on a night train. The choice of travelers on the two ways is determined by both individual preferences and travel costs of different transport modes. Because travel at night by a sleeper train frees up daytime and saves hotel fees. If the ticket price of the sleeper train is similar or lower than high speed train, most passengers would choose sleeper train in long distance trip.

This passenger preference analysis is of crucial importance for building high speed rails in countries with large territory. That means building high speed rail will face serious market risk. High speed means high construction and high operation cost, and high ticket price. How many passengers would like to pay the high price for several hours travel time savings becomes the key issue of the sustainability of high speed rail projects.

3. The problems of building high speed rails in China

Based on the time allocation model and the preference analysis of passengers in long distance travel, two key issues of building high speed rail in large territory countries such as China must be realized. Firstly, only in certain distance high speed train (HST) is faster than other transport modes. Its comparative advantage and market share would decline in longer distance travel. Secondly, the time allocation model predicts passenger prefer night sleeper train rather HST in long distance trip. The two issues make building HSR in China face serious market risk that has been verified by the practice of China.

3.1 The comparative advantage of HST will decline in more than one thousand kilometer trip

The first issue is related with the time constraint (1.4), that is a problem of which transport mode is faster in certain travel distance. Different transportation modes have their own comparative advantage and different market position. On a medium and long travel distance, three transport modes， automobile, high speed train and airplane are relevant to the issues here. From the end to end consideration, the total travel time is not only determined by the operation speed of airplane or HST, but the access time to airport or rail station. For travel by automobile, because of no access time it can be faster than others in a shorter distance travel. The access time has great influence on travel time.

Travel by airplane or HST, the total travel time can be divided into three parts, if transfer between different transport modes is not in consideration. T_a is the total travel time by flight. $T_a = T_{h,a} + T_{f,a} + T_{d,a}$, $T_{h,a}$ is the time from home to airport and before boarding. $T_{f,a}$ is the time of fly. $T_{d,a}$ is the time form airport to destination.

T_h is the total travel time by HST. $T_h = T_{h,h} + T_{t,h} + T_{d,h}$, $T_{h,h}$ is the time from home to rail station. $T_{t,h}$ is the time on the HST. $T_{d,h}$ is the time from rail station to destination.

Airport is usually farther from city center than rail station, and security check is necessary before boarding in an airport, so $T_{h,a} > T_{h,h}$, $T_{d,a} > T_{d,h}$. Even flight speed is faster than HST, in a certain distance S, the total travel time can be the same, that is

$$T_{h,a} + T_{f,a} + T_{d,a} = T_{h,h} + T_{t,h} + T_{d,h} \quad (1.13),$$

let $\Delta t = T_{h,a} + T_{d,a} - T_{h,h} - T_{d,h}$, Δt is the total access time difference between two transport modes. Equation (1.13) can write as

$$\Delta t = T_{t,h} - T_{f,a} = S/V_h - S/V_a \quad (1.14),$$

V_a is the flight speed. V_h is the travel speed of HST. Equation (1.14) means that at a travel distance S, the operation speed gap between HST and airplane just equal to the access time gap between airport and rail station. Then the same distance travel spending the same total travel time by both flight and HST can be written as:

$$S = (\Delta t \times V_a \times V_h) / (V_a - V_h) \quad (1.15)$$

Which means that the same distance and same total travel time by two different transport mode with different operating speed is determined by the gap in access time and the gap of operating speed of the two transport modes.

If Δt =2 h, V_a =650 km/h, V_h =260 km/h, S = 867 km

That means distance within 867 kilometers, HST can be faster than airplane, while above 867 kilometers airplane is faster than HST. Of course, if the gap of access time changes and the gap of operating speed changes, this distance would change. That is why many rail stations stay in city centers, and even the rebuilding costs are very high, which can reduce the access time and increase the attractive of railways. Increasing the travel speed of HST to 300 km/h, within 1114 kilometers HST can be faster than airplane.

Because travel by automobile can go from end to end, if the access time difference of HST and automobile is $\Delta t = 1$ h, and the speed of automobile is 80 km/h, the operation speed of HST is 260km/h, then the same distance travel spending the same time by both automobile and HST is 130 kilometers. That means within 130 kilometers, automobile is faster than HST, above 130 kilometers HST is faster than automobile. Therefore only the travel distance is between 130 to 867 kilometers, HST can be faster than automobile and airplane. That means on this distance the market demand for HST is high, and on more long distance the market demand for HST will decline greatly.

Of course, changing the speed parameter or the access time the result will be different. While one thing is certain, only on certain distance travel HST has comparative advantage than automobile and airplane. This has been verified by the operation practice of HST in Japan and China.

In Japan, on the Tokyo–Nagoya(342 km)–Osaka(515 km)–Fukoka (1070 km) corridor, the HST share of the passenger traffic volume is 100%，80%，9% relative to airlines respectively. This situation has kept for a long time.

In China, the high speed train between Beijing and Shanghai began operation in July 2011, which pass Jinan city. The distance between Beijing and Jinan is 497 kilometers, between Beijing and Shanghai is 1318 kilometers. The distance between Beijing and Guangzhou is 2191 kilometers. The China Railway Authority has not published the monthly passenger traffic volumes in the three sections. While the passenger train schedule show that there are more pair of trains in medium distance and less in long distance. For example in May 2013, there are 69 pairs train between Beijing and Jinan each day, 46 pairs train between Beijing and Shanghai, only 8 pairs train between Beijing and Guangzhou per day. That means as the travel distance increase, the demand for HST decline remarkably.

The monthly airways passenger traffic volume give evidence from another aspect. The high speed train operation between Beijing and Shanghai has nearly no impact on the volume of the airline passenger volume, while between Beijing-Jinan corridor, the airline passenger traffic volume is declining greatly, as show in table 1.

Table 1. Monthly airline passenger traffic volume in different years

	September 2010, Airline passenger traffic volume (scheduled flight number)	September 2011, Airline passenger traffic volume (scheduled flight number)	September 2012 Airline passenger traffic volume (scheduled flight number)
Beijing — Jinan	31858 (233)	20960 (218)	8608 (120)
Beijing — Shanghai	1493307 (5755)	1247100 (5317)	1241643 (5435)

The three monthly statistics in different year show that after HST operation, the airline passenger traffic volume between Beijing and Jinan declined about 70 percentage; the scheduled flight number reduced about 50 percentage. While the airline passengers traffic volume between Beijing and Shanghai nearly kept at the same level.

Both the cases of Japan and China demonstrate that high speed rail can take a big market share on about 500 kilometer's travel market than airplane, but would loss comparative advantage on more than a thousand kilometer travel market.

3.2 Conventional sleeper train has comparative advantage in long distance travel

The second issue about passenger transport mode preference is also related with the time constraint (1.4). The question is in long distance travel passenger will choose a faster transport mode or a slower night train?

Passenger preference can be revealed through a large scale questionnaire analysis, but can also be observed through the choice behavior of passengers. From 2012 a new rail passenger ticket booking system (www.12306.cn) has been in operation in China. Passenger can buy ticket 20 days advance from internet or telephone booking system. Because passenger's name and ID number must be indicated on the ticket, and using other's ticket is not allowed to boarding. This ticket booking system can reveal passenger's preference clearly.

Passenger will buy the first best train ticket, if this kind of ticket is sold out, he will turn to the second best. So what kind of ticket is sold out first can exactly show the preference of passengers. We collect some data of unsold tickets from the rail ticket booking system. The focus is on the two corridors with the largest passenger traffic volume, Beijing to Shanghai and Beijing to Guangzhou. There are two double-track lines on each of the two corridors now, one is HSR another is conventional double-track lines. On Beijing-Guangzhou corridor, the HSR is 2191 kilometers and the conventional rail is 2294 kilometers. In May 2013 between Beijing and Guangzhou, three pair high speed trains operate on HSR each day and five pair trains operate on conventional line each day. It is not the typical case of sleeper train which starts at evening and arrive at next day morning, because there are only 8 pair of trains it can show the passengers' preference more clearly.

On May 13th we entered into the ticket booking system and find the unsold ticket information on May 16th as shown in table 2.

Table 2. Unsold ticket information on May 16th 2013

Train No.	checking scope			unsold ticket number				
	start station	end station	Total operation time	First class seat	second class seat	Soft sleeper	hard sleeper	hard seat
				(price, RMB)	(price, RMB)	(price, RMB)	(price, RMB)	(price, RMB)
K599	Beijing 05:25	Guangzhou 10:50	29:25	--	--	6 (767)	59 (441)	119 (251)
G71	Beijing 08:00	Guangzhou 17:38	9:38	81 (1380)	376 (862)	--	--	--
G79	Beijing 10:00	Guangzhou 17:59	7:59	89 (1380)	606 (862)	--	--	--
T15	Beijing 11:01	Guangzhou 07:32	20:31	--	--	11 (767)	non (441)	180 (251)
G81	Beijing 13:05	Guangzhou 22:32	9:27	109 (1380)	515 (862)	--	--	--
T97	Beijing 13:08	Guangzhou 10:10	21:02	--	--	non (767)	non (441)	143 (251)
T13	Beijing 15:00	Guangzhou 12:43	21:43	--	--	non (767)	non (441)	non (251)
T201	Beijing 18:11	Guangzhou 15:04	20:53	--	--	4 (767)	non (441)	112 (251)

Lowest ticket price or highest speed is not the first choice of passengers. Passengers prefer not too expensive but comfortable hard sleeper trains, its ticket price is 441 RMB and travel time is between 20:31-21:43. All these kind hard sleeper tickets are sold out 3 days advance the trip on the four conventional sleeper trains. The second choice is soft sleeper (ticket price 767 RMB) and hard seat (ticket price 251 RMB), some of these tickets are sold out 3 days advance the trip. On the time all the hard sleeper tickets are sold out, there are at least hundreds of unsold tickets of all the three high speed trains. The last choices are high speed rails which is both expensive (second class ticket price 862 RMB) and spending all the daytime on trip, and the slow train which is cheap but spend more than one day time. This situation is not a special case, everyday is the similar. On other rail sections the situation is the same.

There are 37 pair trains run between Beijing and Wuhan each day, 18 pairs are HST operating on HSR and 19 pairs are conventional train operating on conventional lines. The distance is 1122 kilometers. The hard sleeper tickets are the first choice of passengers, which are usually sold out 2 days advance the trip. The hard sleeper tickets of the train Z37 which start from Beijing at 20:55 and arrive at Wuhan on next morning 6:55 are sold out even 15 days advance the trip. While the unsold ticket number of HST one day advance the trip amounts from 3 to 636, HST tickets are rarely sold out before the trip. China Rail authority has not published HSR's percentage of passenger seats utilization per train, while it is below expectation.

82 pair trains are running between Wuhan and Guangzhou (1069 kilometers) each day, 54 pairs are high speed trains and 28 pairs are on conventional rails. That is the same as other sections, the hard sleeper tickets are usually sold out 3 days advance the trip. The hard sleeper tickets of train Z23 which start from Wuhan at 19:45 and arrive at Guangzhou on next morning 6:05 are sold out 14 days advance the trip. While the high speed train tickets are rarely sold out before the trip.

On Beijing-Wuhan-Guangzhou corridor the hard sleeper tickets are most popular than other tickets, which support our theoretical analysis. On Beijing-Shanghai corridor the situation is the same. There are 46 pairs trains run on the corridor each day, 41 pairs are high speed trains, 3 high speed trains and 2 conventional trains operate on the conventional line. On conventional line the high speed trains start at evening and arrive at next morning in less than 12 hours, and the other two conventional trains need more time. While the most popular train on Beijing-Shanghai corridor is T109, it starts at 19:33 and arrive Shanghai at next day morning 9:55. T109's hard sleeper tickets (316 RMB) are always sold out 4 days or 9 days advance the trip, its soft sleeper tickets (487 RMB) are usually sold out 4 days advance the trip, even T109's hard seat tickets (177 RMB) are always sold out 2 days advance the trip. Only part of the tickets of HSTs (553 RMB) are sold out before the trip, it is always in the weekend in some high speed trains.

The rail passenger market in China is different from countries with small territory such as Japan, Germany and France, where the distance between major cities is no more than 500 kilometers. However, the distance between major cities in China is generally more than 1000 kilometers. In this long distance travel market, high speed train has no comparative advantage relative to airplane, while the conventional sleeper train run at night could have some comparative advantage.

HST can not run during night because of maintenance requirement, also because of no any comparative advantage. HST operating at 300 km/h start from Beijing at 10 p.m., will arrive Shanghai at 3:00 a.m. next morning. The high speed has no value or even negative value. The moderate speed conventional train is more valuable than HST, it starts at 9 p.m. arriving Shanghai at 7:00 a.m. next morning.

Ticket price is another factor determine passengers' choice between HST and conventional train. The railway fare rate of conventional train is 0.10–0.15 RMB[4] for one passenger–kilometer, while the fare rate of HST is up to the level of 0.43–0.48

[4] Exchange rate: US$ 1= RMB 6.3

RMB for one passenger–kilometer, which increase more than 200% at least.

The ticket price of HST is too high for most Chinese people. According to the statistics in 2006, 83.7% rail passengers by hard seat, 10.76% rail passengers by hard sleeper, only 1.26% rail passenger by soft sleeper, while the ticket price of HST is higher than soft sleeper.

The large scale construction of HSR, in fact, is asking most Chinese people pay the price higher than the soft sleeper to travel by rail. China's per capita income is still relatively low, so is the economic value of the time. Therefore, cheap and basically comfortable traveling weigh much more for ordinary Chinese passengers, who would not like to afford three times more ticket price for the sake of only saving several hours of travel time.

High ticket price limit the market of HST. This is a dilemma, because the construction and operation cost of HSR is very high. Lowering the ticket price HST would make loss, raising its price will further reduce the volume of passengers, HST still make loss.

The source of this dilemma is that the technical standards of HSR in China are too high. The target speed of HSR infrastructure is 350 km/h, the rail line uses ballastless tracks, the minimum curve radius is 7000 meters and even in sections with exception the minimum curve radius is 5,500 meters. In comparison, the minimum curve radius of the high-speed railways in France is 4,500 meters and the Tokaido Shinkansen in Japan has a 2,500-meter minimum curve radius. Because of high technique standard requirements in China, there is few choices on the position of the HSR route. If there are hills on the route the only choice is making tunnels but not turning around. If there are residents on the route the only choice is moving them away. These are the key factors that raise up the construction costs of HSR. The high speed standard make the construction cost very high, so compare other countries the HSR building costs is lower one in the world. The cost of building one-kilometer HSR is about two times of conventional railways.

The operation costs of HSR are also very high. The price of Electric Multiple Unit (EMU) with a capacity of 1000 passengers is about five times the price of conventional trains, its maintenance costs is also high. The energy consumption is huge, according to Davis formula, the resistance is proportion the square of the speed of HST. The energy consumption of HST at 300km/h is about two times of that at 200km/h.

High speed bullet train has rather high requirements for the stability of the infrastructure and the smoothness of the tracks, the subsidence of subgrade can be no more than 15 mm. These requirements raise not only the construction costs but also the maintenance costs. While the subsidence after the construction will undergo several years' process, for the ballastless track, if there is subsidence, no one knows how to deal with. There is no available method. This is the real technique risk in the huge HSR network in China.

The construction and operation costs of HSR are excessively high and the scale is extremely large, while the Ministry of Railways (MOR) were financially fragile. MOR had both the government function and enterprise function, for a long time it was the only government department combines the two roles in China. MOR directly managed the operation of rail system and responsible for new rail construction. The financial source of construction come from "railway construction fund", which in fact is a kind of tax levied on cargo shippers. Every year MOR had about 65 billion RMB construction fund revenue which could be used in new investment. In 2010, the total transport revenue of MOR was 449 billion RMB, while the total investment amounted to 842 billion RMB. MOR was entirely relying bank money for HSR construction.

The asset-liability ratio of MOR was 38.7% in 2004, while in the end of 2012 which is rising to 62.2 %, the debt amount to RMB 2.79 trillion. The railway construction fund revenue can not cover the interest of loan. The rapid rising of asset liability ratio is inevitable during large scale construction, while the most serious problem is that the cash flow of MOR is nearly broken.

In March 2013, MOR was abolished, its government function was incorporated into the Ministry of transportation. All the enterprise functions of MOR are taken by the China Railway Corporation, who will carry all the debts of MOR. While the new company has no capability, as the same as its predecessor, to repay the principal of the debt.

3.3 HSRs in China face great market risk

For all new HSRs in operation are in loss. Beijing-Shanghai HSR and Wuhan-Guangzhou HSR are located in the most prosperous areas where the population density is the highest in China. Yet both of them are in loss. The Zhengzhou-Xi'an HSR, located in the central west part of China, began operation in Feb. 2010, which is about 500 kilometers. At this length HSR should have comparative advantage, after HSTs in operation airlines stop operation between the two cities. HSTs only needs 2 hours and a quarter minutes from Zhengzhou to Xi'an, its ticket price is 230 RMB. While on the parallel existing line, the conventional trains are much cheaper, for hard seat only 73RMB, hard sleeper 133RMB, soft sleeper 201RMB, from Zhengzhou to Xi'an they run about six and half hours. In May 2013, There are 37 pairs of conventional trains each day on the existing line, but there are only 24 pairs of HSTs operating each day on Zhengzhou-Xi'an dedicated passenger lines, even after Beijing to Zhengzhou's HST has been in operation. While the carrying capacity of Zhengzhou-Xi'an HSR is 160 pairs each day. This is similar to build a luxury hotel with 160 floors, only 24 floors in operation, and other 136 floors are totally in idle. These kind of luxury hotel is unsustainable, the same as high speed rails.

China will face the same problem of how to give subsidy to HSR in other countries and areas, but more serious because of its large scale. Except for the 500 kilometer HSR between Tokyo and Osaka, all other HSRs in the world fail to make ends meet. Because no places in the world can match the corridor between Tokyo and

Osaka, which concentrate about 70 million people and 70 percentage of GDP in such a narrow strip. High-speed railway companies in South Korea are struggling with huge deficits. In Europe, governments regard it as natural to subsidize passenger railway transport services. The TGV South East in France (Paris-Lyon) was thought as covering its costs, while the French government give France railways subsidy amount to 10 billion Euros each year. If Paris-Lyon high speed rail operate as an independent company, whether it could cover its total costs is doubtable.

For any means of public transport, “the faster, the better” is not what matters. Instead, it should strike a balance between the cost and benefit (that passengers receive). Take for example the Concorde jets, which were put into commercial use in 1970s. With an average cruising speed of 2,150 km/h, the Concordes take only three hours and a quarter to fly from Paris to New York. Considering the time difference of six hours between the two cities, the passengers could actually “arrive before you leave” as the adverts said.

But only a few customers were able to afford or were willing to pay the extremely high-ticket price to fly Concorde. With high operating costs, Concorde was unsustainable commercially and in 2003 after 27 years’ operation relying on government subsidies it ceased commercial operation.

This is a typical case of an unsustainable transportation means whose total cost surpasses the total value of travel time saved in the long run. The large scale construction of HSR in China will face the same problem of Concorde, but more serious than it, because huge money have turned into concrete and steel as rail infrastructure.

China should build more rails, but not high speed rail, till 2020 China should have 160,000 km rails, but not 120,000 km planned by government. Even if this goal of 160,000 km is realized, China's railway network density still cannot reach India's level in 1950, even the quality has great difference. The target speed of high speed rail in China should be no more than 200km/h. While regardless of national conditions, the blind pursuit of fast and high-standard HSR construction fails to address the problem that present railways cannot meet the needs of national economic growth. According to the statistics of the Ministry of Transportation in 2008, 640 million tons of coal was transported by truck across provinces, because of the shortage of rail transport capacity.

The most serious problem of HSR in China is the speed target is too high that it can not be compatible with the existing lines. The conventional passenger train can not operate on HSR. The HSR in fact is not dedicated passenger lines. Because lots of conventional passenger trains still operate on the parallel existing lines. The transport capacity in existing parallel rail lines such as Beijing-Shanghai and Beijing-Guangzhou existing lines are not fully released. Huge investments in HSRs do not break the bottleneck of rail transport capacity. China would face the transport tension in existing lines combined with a huge waste in carrying capacity of high-speed dedicated passenger lines. A debt crisis of railways combines with a huge bank defaults in the financial system, which will become a serious drag on economic development of China.

References

Baker, Gary S., 1965. A theory of the allocation of time. The Economic Journal 75 (299), 493–517.

DeSerpa, A.C., 1971. A theory of the economics of time. The Economic Journal 81 (321), 828–846.

Johnson Bruce, 1966. Travel time and the price of leisure. Western Economic Journal 4, 135–145.

Oort, C. J., 1969. The evaluation of traveling time. Journal of Transport Economics and Policy 3, 219–286.

Small, K. A., 1982. Scheduling of consumer activities: work trips. American Economic Review 72, 467–479.

Bates, J., Polak, J., Jones, P., Cook, A., 2001. The valuation of reliability for personal travel. Transportation Research E 37 (18), 191–219.

Jara-Diaz, S., 2003. On the goods-activities technical relations in the time allocation theory. Transportation 30 (3), 245-260

Meilan Jiang , Takayuki Morikawa, 2004. Theoretical analysis on the variation of value of travel savings. Transportation Research Part A 38 (2004) 551–571.

Zhao Jian, 2006. The risk of develop high speed passenger dedicated railway. Comprehensive Transportation August 52–55. (Chinese Journal)