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Human Oriented Package of BRT Station Design, a Sustainable Approach

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ABSTRACT

A city is a complex system with diverse constituent parts which have strong connections with each other. Public transportation is an important and challenging part of this system. Nowadays, using public transportation is preferred to use of private cars in mega cities because of negative effects of traffic issues on national economy, environment and CO₂ emissions. There are different types of public transportation systems; one of these constituent parts is BRT (Bus Rapid Transit). This type of transportation is important because lots of people, in mega cities, need it to reach their destinations daily. There are several investigations about bus stations in the past; each one focused on a part of this field of study. These studies aimed to decrease the negative effects on the environment, optimize the overall cost, and increase of passengers' convenience. Corridor type and the distance of people's walk in BRT stations were studied to find the influence of the parameters on passengers' decision for transportation type used. Also, the optimum number of bus stations in Sydney was investigated to minimize the cost and delay of BRT system in the city. A new-shaped bus-bay to increase the safety and convenience for passengers in Tokyo was studied as well and a method to estimate the bus station type and its scale, and a bi-level model for determining the bus stop area to minimize the total cost of system considering the passengers need are some other investigations in this field. However, in our survey on previous models of BRT system, lack of sustainable factors was identified. This factor was developed in the area of urban furniture design and was added to our package. To develop and classify the factors, we studied the participants' behavior in the environment and analyzed their communications and behaviors. The outcome of this study is a package for designing a BRT station based on sustainable design approach. The package enhances the quality of public transportation services and encourages people to use buses instead of their own cars. For this purpose, the sustainable factors were combined to machine oriented model based on literature and human behaviors to finalize the package. This package, in contrast to the previous ones which were machine oriented, is human oriented. Human orientation method improves the system to be more commensurate with people's needs, and consequently creating safe, comfortable, and sustainable conditions.

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INTRODUCTION

One great challenge in metropolises is an efficient transportation system. Nowadays, public transportation is preferred to private cars in metropolises because of negative effects of traffic problems on economy, environment and climate changes [1]. Bus Rapid Transit (BRT) which is fast, comfortable and economical urban transportation, is a high quality fundamental transportation system. It provides a separate infrastructure that aims to prepare frequent operation and supremacy in customer service and marketing [2]. Definition of "rapid bus" is used for different public bus services. Actually; there is a spectrum of BRTs from BRT-Lite to full BRT. This spectrum includes: 1. unofficial transportation services 2. common bus services 3. bus basic routes, 4. BRT-Lite, 5. BRT, 6. Full BRT [3]. The outcome of Hensher *et al.* [4] studies shows that even in low income cities BRT's popularity is growing increasingly because of offering high quality mass services in accordance with municipalities' budget. Macario, Filipe [5] found out that, in order to make successful the BRT systems, they need to be considered as part of a broader policy package. Instances in BRT implementation include decision making on multiple options by considering the whole system. Some of these options are, in

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fact, independent criteria (e.g. building infrastructures, organizational arrangements, modifying traffic regulations, etc.) which are necessary in a system implementation routine. Hence, BRT system can also be independently considered as a policy package. Besides, secondary criteria (e.g. environmental regulations, fine for making congestion ...) are important in system's efficiency, so they should be taken into consideration. These criteria affected by BRT system positively.

There are several studies on bus stop specifications to decrease the overall cost and increase the passengers' convenience [1-25]. Jiang *et. al* [21] investigated on walk access patterns i.e. corridor type and the distance of people's walk in BRT stations to find the influence of the parameters on passengers' decision for transportation type used. Tirachini [22] studied on the optimum number of bus stations in Sydney to minimize the cost and delay of BRT system. Nakamura [23] introduced a new-shaped bus-bay to increase the safety and convenience for passengers in Tokyo. Hongwen *et. al.* [24] introduced a method to estimate the bus station type and its scale to meet the passengers need. Ibeas [25] suggested a bi-level model for determining the bus stop area to minimize the total cost of system considering the passengers need. Macario, Filipe [5] introduced a BRT implementation policy package, considering six different factors, which include: 1. Integration, 2. Financing, 3. Popularity, 4. Business services, 5. Physical setting, 5. Environment and energy. In a research done in Living Lab framework in the city of Schwechat [6], public transportation stations were scrutinized as multipurpose centers for regional innovation and local developments. This survey shows that by integrating the stations as a place for social activities, public transportation functionality will be enhanced. Regarding Schrenk and Benedikt's [6] findings, there are some important characteristics to design bus station well: safe and direct routes to all accessible areas in a bus station, appropriate waiting room with facilities to seat, lie down, or take shelter, offering a broad range of information, comfortable and accessible entrance facilities, special facilities for people with physical disabilities. However, study on literature shows that, design factor was not taken into consideration as an important and independent factor to model the traditional transportation packages. Thus it is necessary to include design parameters in tradition models of BRT packages.

In a survey done by Din *et. al.* [7] the characteristics of some station furniture's elements have been identified and bus station as one of these elements can be designed in accordance with those characteristics which include: aesthetics, sufficiency and durability, ease of use and safety, simple construction and maintenance, urban identity, and finally environmental sustainability. The design factor should be interacted with other factors of the implementation package of BRT system. Hence, this can help the administrators to make a policy to increase the efficiency and quality of BRT system. Since the sustainable design is based on economic, environmental, and social principles, it is important to add the sustainability parameters for BRT system design. Therefore, this research aims to enhance the functionality and meet the future design needs of the BRT station utilizing the industrial design factors in BRT policy package. According to the mentioned above a package is developed in this research to include the important criteria that other researchers neglected them. The research procedure includes a) experts and users interviewing, b) monitoring behaviors of BRT users, and c) analysis of the observations which are described, d) introducing the final package. For this purpose a questionnaire was extracted based on related literature [7, 9, 11-19].

Methodology:

In this research, two significant models developed by Macario [5] and Din *et. al.* [7] who have mentioned some of the essential aspects of designing a BRT station were used as the base of new BRT package. Actually, utilizing these models is an appropriate beginning to develop a package for designing a BRT station based on sustainable design or environmental oriented design. Therefore, the new package is based on two mentioned models above and recognized method of sustainable design. In this research, the design of a "rapid bus" station has been accomplished in accordance with the customers' needs based on Ulrich [8] method in six stages. The first stage has been started with literature research to derive the basic principles, and compare our project with the successful projects across the globe. In this stage, the significant foreign projects and domestic projects were investigated and analyzed regarding the local attributes. Therefore, the research process was arranged according to the customers' needs using a 360 degree feedback of user to focus on the interaction between user, environment and product (BRT station in this research). In this process, all necessary facilities and services for each station were regulated then compared to design standards of bus stations. Afterwards, in comparison to successful samples, each station was assessed in three different areas of place, user and subject in order to identify their strengths and weaknesses. Also, a morphological analysis method which assesses all components of problem in detail is utilized. In the next phase of field studies, we developed a questionnaire employing interviews and observation of users' behavior in place. We designed the questions in a way that customers would express their opinions and requests without being influenced by any external thought [8].

Scope of research:

In order to acquire the criterion of model's factors, it is necessary to perceive the customers' apparent and latent needs in environment. To derive the customers' needs, their characteristics were investigated in three

areas. We do not consider a bus station as an individual product which does not have any spatial relation with its environment, yet we examined its relation with subjects presented in the station. These three areas include:

- Thematic Domain
- Spatial Domain
- Usage Domain

Thematic Domain: the output of this project is a bus station which, in design area, is considered as urban furniture. A bus station is one of urban elements that has an important role in the appearance of urban environment due to its structural characteristics [10]. The most important issue in thematic domain is damage. The damage factors can be categorized to intentional and unintentional factors which were examined in four groups of user, product, environment, and designer. Figure 1 shows the damage factors.

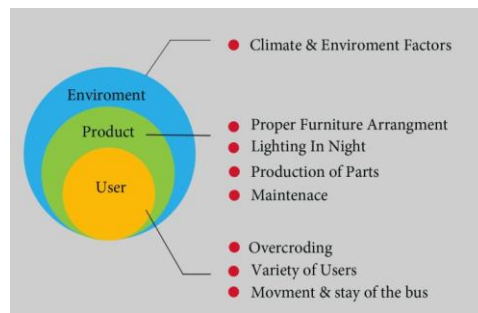


Fig. 1: Thematic Domain.

Spatial Domain: to study the spatial Domain of Bus stations, as shown in Figure 2, analysis was done in three levels of environment, user, and station facilities.

- 1- The station with its surrounding environment, as part of a system, interacts with all components of the transportation systems. In other words, more interaction results in faster transportation.
- 2- Passengers are the main users of bus stations who interact with all the facilities and furniture of the station. Interaction of passengers, improved with the station, results in the quality enhancement of whole transportation system.
- 3- All the facilities in a bus stations interact with each other. Staying in the station, even for a short period of time, must be a safe experience so the users satisfied their basic needs.

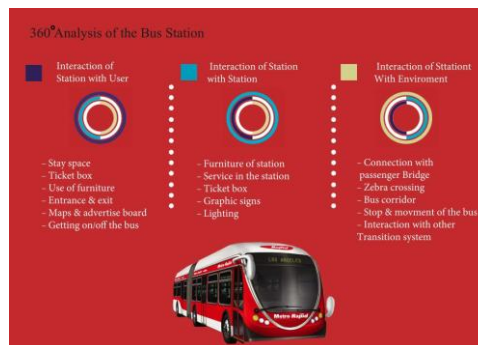


Fig. 2: Spatial Domain.

One of the principles of sustainable design is the application of added values. Applying added values advantages in design not only glamorizes the final product, but also reduces the number of useless components of product [11]. Multi-purpose products with diverse functionalities can reduce the cost and increase the welfare. To achieve a multi-purpose product it is necessary to reach a complete feedback from product and all stockholders using it. 360-degree feedback, also known as multi source assessment, is a suitable method to reach a complete report from product and all internal and external stockholders. Actually, 360-degree feedback is a response that records from members of an organization, such as employees, managers and also users, which have interactions in a work circle. Therefore, a complete feedback can take from both internal sources (employees and owners) and external one (customers and suppliers).

Regarding this principle, usages and values existing in stations are presented in Figure 2 by 360 degree feedbacks. 360 degree feedback method was applied for user domain analysis. In the figure three main factors

were investigated which include interaction of station with environment, station with users, and station with facilities.

User Domain: users will be categorized and their morphology will be developed. Based on the chief purpose of the product usage, users will be level according to the functionality of the station which is transferring the passengers, as part of the city's transportation system. The first level of users are passengers, the second level of users, regarding the period of their stay at the station, are the station's employees, and the third level ones, regarding their indirect relation with the station, are bus drivers. As Table 1 shows, users have been classified according to the above mentioned levels and placed in six different categories: 1. Gender, 2. Type of utilization, 3. Time of utilization, 4. Basic needs.

Table 1: User Domain.

	First level users	Second level users	Third level users
User	Passenger	Employee	Drivers
Gender	Female/male	Female/male	Female/male
Type of utilization	Short walk/stay	Service/Security /Supervision	Short walk/stay
Time	Waiting	Long stay	Waiting
Primary needs	Safety Ease of access	Safety in the station	Safe connection Sufficient space

Analysis of Users' Morphology:

Regarding to the complementary analysis of users in Bus stations, it is essential to analyze the design approaches, cultural characteristics, social values in urban interactions, users' gender and age to discover users' special needs. Actually, all people are not the same so some of them which are not as strong as others such as, children, pregnant women, old and disabled people have different needs compare to other people. Dealing with a complicated problem, where there are numerous governing factors that cannot be detailed as numerical time series data, needs to analyze it morphologically. However, the traditional approaches are used to separate the system into small parts dropping the insignificant components to introduce the desired models. The drawbacks of using these methods are that in real cases the model introduced may not behave logically. From the other point of view, morphological analysis method does not omit any parts from the system itself. Therefore, morphological analysis, saving all components of system, causes to investigate a full interaction analysis in real-world problem.

In morphology analysis of users, their cultural traits in interaction with bus stations have an important role. Separate doors for men and women entries and even separate seats in the bus, shows an emphasis on the Iranian culture. Based on observations, a certain space between the passengers is important for all users, and this space will make passengers moving easier in stations. As shown in Figure 3, the users' morphology in three levels of users' gender, special users, and types of utilization has been studied.

Questionnaire:

A list of questions which had to be applied in a better design of a bus station was recorded as the questionnaire. It has to be noted that some questions were outlined by observing users' behavior in interaction with the station. The questionnaire was designed using literature related to sustainable design [7, 9-13, 20]. Also, the questionnaire is designed based on principles of industrial design, 360 degree-feedback [14, 15, 18] and morphological analysis [16, 17, 19]. The questionnaire has been tested several times by research and analytical methods, mentioned in this paper. The validity of this questionnaire was confirmed by experts. The questionnaire was distributed among different users, such as passengers, managements, drivers, and employees of the stations so that all variety of demands was collected. The answers were given in Likert scale which is a five-rating answer to questions. Hence, opinions from very important to extremely unimportant can be collected.

RESULT AND DISCUSSION

Considering design obligations and having a sustainable approach in design, resulted in the evolution of the package proposed in this research. Tree groups of models were used in this study to design a questionnaire based on the literature related to the BRT field. First group is sustainable models [5] and second group is industrial design model. At the beginning, this evolution was achieved through factor analysis which classifies the questionnaires results in different groups. Continually, these groups which determine the final factors were filtered by analysis and assessment methods. These methods include analysis in thematic, usage, and spatial domains which were conducted through observation, interview, questionnaire and assessment of successful models. All the information can be seen in the Figures 1-3 and Table 1.

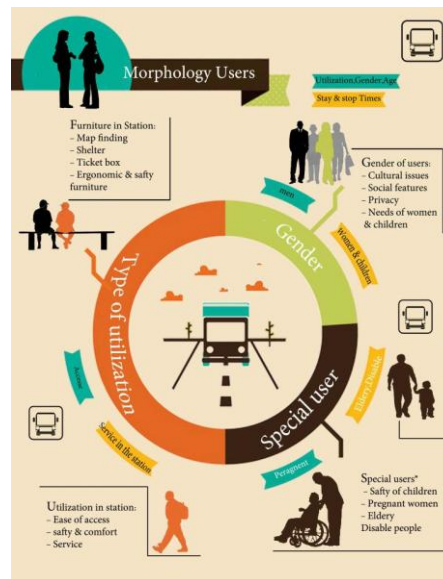


Fig. 3: Analysis of User's Morphology.

Questionnaire analysis:

Reliability of the questionnaire was determined by Cronbach alpha with the result of 0.889. Since the result is higher than 0.7, therefore the answers' authenticity are confirmed. The answers in Likert scale was analyzed by SPSS software and classified by Factor Analysis.

Factor analysis is a statistical based method which is used to assess variability of observed. This method investigates the data obtained from variations to find unobserved hidden variables. Factors which are assumed as related variables take the lower number of unobserved variables potentially. Actually, this method is used to decrease the variables set in questionnaire based on interdependencies of observed variables. In other words, this technique is used to determine the low rank approximation between matrixes of observed variables. This method is a linear combination which models the observed variables of the potential factors. Also, this method considers "error" terms in the linear combination. Finally, using factor analysis, the answers were classified into 9 main clusters including:

1. Interior equipment
2. Energy usage
3. Services
4. Form design
5. Universal design
6. Side services
7. Interaction with transportation network
8. Revenues
9. Station facilities.

Final package description:

This package presents the industrial design criteria considering the sustainable approach. These criteria are the results of studies on customers' needs, monitoring users' behaviors, criticism and scrutinization of similar models. The model of BRT station design implementation with sustainable design approach is a result of analysis of each factor by factor analysis method. The added criteria to each of the factors have led to increase the advantages of this package. The final package which is the outcome of investigation mentioned in this research is shown in Figure 4.

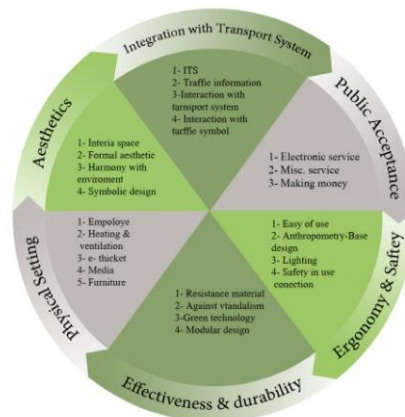


Fig. 4: Human Oriented Package of BRT Station Design.

The elements of the package proposed in this study include the following items:

- **Integration with Transportation System:** Criteria include interaction with physical elements, traffic information and accordance with the intelligent system can be seen in this group. Integration with transportation system will enhance the efficiency of public transportation.
- **Public Satisfaction:** criteria such as offering special services and adding visual flaunts to attract citizens are presented in this group. Adherent to sustainable design principles, one should reduce the diversity of applied materials in a model. In most cases, adding unnecessary secondary usages leads to the complexity of the design. In fact, to design the secondary usages, designer should not add unnecessary complexities to the leading design.
- **Efficiency and Stability:** in order to have a sustainable design, consideration of materials, anti-vandal design, clean energy, and modular design is essential. According to the sustainable design principles, products which are designed to enhance efficiency but their stability and durability is not that much taken into consideration may be out of order before the updating phase begins. A modular design not only facilitates recycling, but also makes the product maintenance easier and as a result increases its longevity. Modularity of design also leads to a better and more efficient production.
- **Physical settings:** furniture which is existed in the station is a part of system that helps the users to feel convenience and ease of use. It should be mentioned that complementary station furniture includes station equipment and employees.
- **Aesthetics:** in line with aesthetic appearance of the station, considering symbolic design, environment oriented design, beauty of forms and visual flaunts are of great importance. According to the principles of sustainable design it is better to design various parts of a product by a single material. Thus, recycling will be easier and more efficient.
- **Ergonomic and Safety:** in agreement with anthropometric measurements, user-oriented approach, safety of passengers while getting in/off the bus, and finally the station's lighting which is a key factor in users' safety, are important factors. Also, in line with the sustainable design principles safety, long life products have to be made. Actually, future generations should not be managed to under potential risks due to our neglecting in designing and creating products, processes, and standards.

Conclusion:

In this research, drawback of traditional models of BRT station was investigated. The literature shows that current models of BRT station design have not considered the sustainable and industrial design principles. Therefore, in this study, both transportation aspects and sustainable industrial design principles are integrated. Introducing a new package was bound to a comprehensive multi-dimensional research. Employing sustainable design principles does not necessarily reduce the quality of life but needs some changes in human minds and their values in modern life. These changes have to be made in international interactions, environmental supervisions, social responsibilities and economic opportunities.

For presenting a new model, a questionnaire was designed to collect people's opinion and use them as some design factors. However to complete and analyze the users' apparent and latent needs in interaction with environment and transportation system, the industrial principles are employed. Factor analysis method was used to distinguish principal factors in the new model. Also, these steps were passed: 1. Study of destructive factors, 2. 360 degree feedback of bus station, 3. Study of users' morphology. Finally a package for designing bus stations was introduced. This package is in accordance with users' needs, BRT characteristics, and can solve future demands of transportation system.

Generally, this research shows that improving public transportation system will result in its popularity, reduction of air pollution, and ease of urban access, all due to providing appropriate furniture which consider in this paper. The introduced package, in addition to an administrative and policy-making, is a sustainable industrial design approach. Also, this model is a suitable package for those designers who have a user-oriented style. Actually, this package, in contrast with the previous ones which look at rapid bus transportation system as a machine oriented policy package, puts people at center of designing rapid bus station.

Further studies can be done on these topics:

- 1- Adaptation of proposed package to other transportation systems
- 2- Combining the introduced package with intelligent traffic and transportation system

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