The production (or industrial) engineer’s role allows the planning of industrial facilities in a way to eliminate or minimize different forms of barriers that can appear during the phase of planning the facilities, making the industrial work environment accessible for disabled people or people with mobility impairments. Though, the main reference works used as national and international reference for the planning of industrial facilities have insufficient or inexistent content about the necessary adaptations to make these individuals’ inclusion possible. This research intends to fill this gap through a model that can be used as guide for the planning of industrial facilities to make the project accessible from the conception. This model was developed considering the necessary demands to the inclusion, through the incorporation of related information from outside the factory (social environment) to the workstation. Therefore, these demands were identified by different means: i) bibliographical research based on legislation, effective normative instructions, inclusion models and project techniques; ii) in a participative way with professionals of different areas of performance, part of assistance entities and from the disabled people; and; iii) a case study accomplished in an industry that works with disabled people. The elaboration of a model compatible with the language used in the engineering area was searched, which was denominated “Conceptual Model for the Planning of Industrial Facilities Free from Barriers”. The final considerations show the existence of demands for inclusion even related to the production system and work organization, suggesting that integrative solutions, as the one of the proposed model, should be used in the formation of the future production engineers.

Palavras-chaves: Social Responsibility, Accessibility, Disabled People, Production Engineering, Planning of Industrial Facilities
1. Introduction

The long business life has been directly related with the creation of a maintainable model of
development for the whole society, being the social inclusion one of the critical factors for the
survival of the company in the current globalized market (ETHOS 2004). That context
includes actions that privilege the promotion of health in the working environment, the
incentive to diversity and the inclusion of portions still marginalized of the population, as the

These actions represent more than aspiration for a fairer society, in fact, they are part of an
international commitment of the signatory countries of UN since 2000; in order to obtain an
"Inclusive Society" in the next eight years (up to 2015), through the "Goals of the

The promotion of accessibility has been searched even through the elimination of access
barriers (ADAABA, 2004; ADA, 2003). According to the Brazilian legislation n° 10.098,
2000 (BRAZILIAN LEGISLATION, 2004), access barrier is "any impediment or obstacle
that limits or impede the access, movement freedom and the safe circulation of people", so
much the barriers in the passages or spaces of public use (architectural town) as inside the
public and private buildings (architectural construction), in the means of transport
(architectural in transport) or in the means of expression and reception of messages
(communication barriers). The elimination of these barriers enlarges the scope of inclusion,
and seeks not only to benefit the bearers of disabilities but also anybody with reduced
mobility, temporary or definitive.

It is important to highlight that all the individuals, in some moment of their lives, have
reduced mobility, temporary or permanently. The very big or very small person, the pregnant,
the ones who are carrying bags, luggage, materials or pushing a baby stroller, or even when
children or elderly; people that broke an arm or sprained the ankle, everybody already needed,
needs or will need means for locomotion and/or communication (ETHOS, 2002;
AMIRALIAN et al., 2000). This aspect puts the search for inclusive solutions as something of
general interest and not just of some minorities, seeming even more reasonable to say than no
inclusive projects are actually ineffective to assist the inherent demands of the human beings
in all their diversity.

This global movement points at the need of rethinking how each professional can contribute
in his/her area of performance in the search for a better society (WORLDWATCH
INSTITUTE, 2004). And, with this perspective, the production (or industrial) engineer can
also contribute, especially concerning the scope of planning industrial facilities
(BITENCOURT et al., 2005).

This context justified the need of industrial facilities planned in a way to be exempt of barriers
that impede or hinder the safe access and circulation of people, including people with
disabilities or with reduced mobility (BITENCOURT et al., 2004).

However, under the scope of the production engineering, this is still an incipient area of
research and, although the engineer searches for complemental information in order to make
an industrial installation free from barriers possible, he would hardly be successful in this
taskwork. This is due to the fact that this information is dispersed so much in the literature
(legislation and normative instructions related to the inclusion, inclusion models and project
techniques) as in the practical experiences of individuals in the different areas of knowledge,
of different entities and the disabled people (BITENCOURT et al., 2005).

In this approach, what is intended with the present study is the development of a conceptual
model that can be used for the planning of industrial facilities in a way to make a project free
from access barriers possible. This model should integrate the necessary requirements for the
accessibility, incorporating variables related so much to the external and internal environment
of the installation.

2. Engineering and Accessibility: projects and inclusive solutions

The state of the art in what refers to make it possible to include people with disabilities or
with reduced mobility has been focused on one side in projects of residential facilities
(FRATTARI et al., 2007; NIVA & SKAR, 2006; JOHNSON & KASTNER, 2005), public
municipal environment (ARAÚJO et al., 2007; BINS ELY et al., 2006; MIYAZAWA, 2004);
including educational environments (NJSCC, 2007; GILMAN, 2007; STEWART-POLLACK &
PILLOTE, 2006; IGRIC, 2004), hospitals (LICHT, 2007) and means of transportation
(FIELDING, 2005).

In these projects different techniques have been developed and applied, among which the
aggregation of principles developed by the University of North Carolina in 2003
(UNIVERSITY OF NORTH CAROLINA, 2003), called Universal Design - UD. UD is based
on principles of independence, equality, adaptability and safety, among others, in order to
develop environments usable for the maximum people possible, with minimum or no
additional costs. However, the practical applications of the Universal Design in the industrial
section have been limited to the Design of products (EQUAL, 2003) and not to the planning
of the industrial facilities (BITENCOURT et al., 2006).

In what refers to the projects of facilities, the researches that seek to support the planner
through tools (software) like CAD - automation systems for the support to planning stand out
(ERIKSSON & JOHANSSON, 1996). Some of these researches look for the identification of
requirements (inputs) to feed these systems with appropriate parameters (LAI & CHEN, 2006;
GURALNIK & FERRUCCI, 2003). The research of Bengtsson et al. (1996) search to emulate
work and residential environments through computer simulation; where the authors propose
the use of more realistic animations than the two-dimensional ones, facilitating like this the
verification of the adaptation of the environments for the accomplishment of different
activities.

These researches summarize the main focus of study on the theme; however, they do not
specifically link to the scope of the planning of industrial facilities. Still, most of them look
for solutions under a micro-oriented focus and limited to a group of requirements related only
to the physical aspect of the accessibility.

In what refers to the models for the planning of industrial facilities, no lines of research in
process were identified in the national and international literature related to the theme.
However, references on the compulsory nature of the Americans with Disabilities Act - ADA were identified in the work of authors like Lee (1998) and Tompkins et al. (1996). In this aspect, Lee (1998) just brings recommendations about the need of following the act. Tompkins et al. (1996), besides recommending the use of the same act, make other considerations on the subject in the item denominated "barrier-free compliance", where they approach the theme pointing the anthropometric differences among the people that use a wheel chair for locomotion and the ones that do not. According to the authors, such differences should be reflected at the workstation, in tables and reach areas. In fact, this work does not unfold other demands to be covered and do not bring orientations about the tasks to be accomplished so that the project resulting from the planning can be considered free from barriers, and in order to make the access possible to the maximum number of people possible, where the disabled people or reduced mobility persons are included.

Still, it is highlighted that none of the researched models considered a more effective application in terms of legislation, or even guidance related to the industrial environment and the scope of the production engineer's performance. Subjects related, for instance, to the production process or the organization of work, were not identified in the review accomplished, identifying an entire research line still lacking of studies. It is in this aspect that the present research intended to bring contributions.

3. Materials and methods

The activities accomplished along this research to make the proposed objective viable are presented here in a summarized way: I) finding of the demands for inclusion with base on different sources of knowledge, tacit and literary, gathered in an integrated way and convergent to the focus of interest of this research; II) validation /identification of the demands with base on a real context of inclusion, through the accomplishment of a case study in an industry that works with disabled people in the factory ground and; III) proposal of the conceptual model for the planning of industrial facilities free from barriers with base on the information obtained in the previous stages of research. It is emphasized that all the participants of this research signed a term of free and informed consent, as prescribed by the resolution 196/1996 of National Council of Health of Ministry of Health published in the Diário Oficial number 201, 16/96.

Stage I had as objective to interpellate the biggest number of demands possible for inclusion of disabled people or people with mobility impairments in the job market, in order to elaborate a listing of these demands with base on different sources of information, being: or

a) Literary Knowledge: the technical procedure used was the bibliographical research of: i) legislation and effective normative instructions related to the inclusion: the sources of information used were CORDE (2006), MTE (2006), FADERS (2006), ABNT (2006), Act Planning (2005), Brazilian Legislation (2004) and ADAABA (2004). The complete (population=sample) and systematic reading was made of a total of 143 documents; the scope of this research approached in Federal extent the Brazilian and mentioned North American Legislation; ii) inclusion models and national and international project techniques: this information was interpellated with base on the representative models of national and international institutions that act on behalf of the inclusion, through
asystematic research including: International Labor Organization, World Health Organization, Coordenadoria Nacional para Integração da Pessoa Portadora de Deficiência, Associação de Pais e Amigos dos Excepcionais, ETHOS Institute, among others; iii) scientific journals, national and international thesis and dissertations: through complete systematic research in banks made available by the “Portal de Periódicos da CAPES”. This portal offers access to the complete texts of articles of more than 12,365 national and international magazines, and 126 data bases as described in CAPES (2007). Each publication related to the theme was analyzed as for its applicability and contribution to the present research.

b) Tacit Knowledge: it was searched to know the perception of professionals of different knowledge areas, members of entities and the disabled people, regarding the demands for the inclusion of people with disabilities in the job market and, specifically, in the industrial section. A total of one hundred and ninety three individuals participated in this stage of the research in a direct or indirect way. The finding of data was accomplished in agreement with the first three stages of the participative toll Macroergonomic Design - MD (FOGLIATTO E GUIMARÃES, 1999): i) identification of the user and organized collection of information, ii) Prioritizing of the Items of Ergonomic Demand identified by the participants and; iii) Incorporation of the specialists’ opinion. Open interviews were used, which were recorded and in agreement with the order and frequency the items were mentioned, a weight related to the importance was given in order to elaborate the questionnaires. For the mensuration a continuous scale of 15 cm was used, with two anchors in the extremities, as suggested by Stone et al. (1974). The data of the questionnaires was tabulated and prioritized, and the weight of the item was generated by its arithmetic mean, being used of descriptive statistics. The analysis of consistence of the results was accomplished in agreement with the Alpha of Cronbach (CRONBACH, 1951), in which an alpha superior to 0.56 (alpha = 0.71) was obtained, indicating good internal consistence. The data did not present normal distribution, so it was Kruskal Wallis's statistical test (JAQUES, 2003) to compare the answers in function of the respondent type. The results with statistical difference (significant Kruskal Wallis to p-value <0.05) were analyzed with no-parametric test of complementation of averages.

In Stage II a case study was accomplished (SILVA E MENEZES, 2005), with the aim of validating/ identifying the demands with base on a real context of inclusion and in a participative way with individuals that had contact with successful cases of inclusion of disabled people in the factory ground. The validation of the real applicability of the group of demands for inclusion identified in the previous stage of the research was also searched. The study was accomplished along ten months, period between August 2005 and May 2006, in a company of the industrial section (BITENCOURT et al., 2006). This company is located in the state of Rio Grande do Sul (Brazil), belonging to the shoe section and classified as Degree 3 risk. Today the company counts directly with fifteen employees with disabilities working in activities related to the factory ground, in the following proportions: mental disability 80% (12); physical disability 13% (2) and hearing impairment 7% (1). The experience lived by the company is a differential for research, also because the demands related to the inclusion of people with disabilities are practically not approached by the national and international legislation.
In this stage of the study the direct and indirect observation was used, and to identify the demands in a participative way, also the first three stages of the DM tool were used. In total there were five hundred and fifty nine individuals involved in direct or indirect way, and the employees selected to answer questions related to the inclusion process were chosen in function of working directly with disabled people. In the same way that in the previous stage, the participants expressed their opinions through no induced interviews that originated the questionnaires. The analysis of consistence of these questionnaires was also accomplished in agreement with the Alpha of Cronbach, and the Alpha indicated good internal consistence.

Stage III presents the proposal of the conceptual model developed. With the objective of using a language close to one of the engineer's work routine, the proposed model was structured with base on a model for planning of industrial facilities with recognized acceptance by the academic community. However, along the research it was identified that there is no consensus in the literature about the theme. This way, the model was chosen based on the bibliographical references indicated for the disciplines of "Factory Project", or similar disciplines, taught in courses of production engineering. With the structure defined, the demands were analyzed individually as for its applicability along the stages of the planning of facilities and the case study made the validation of those possible, in agreement with the studied scope. After the demands were organized in a synthetic and taxonomic way as activities and actions executable along the planning, seeking that the final result is free from barriers.

4. Results

The total group of identified demands through the Stages I and II includes the demands with base on the literary and tacit knowledge, and the demands interpellated through the case study, which include from subjects related to the external environment of the industrial installation, as the local accessibility, including means of transportation and accessible routes, to demands related to the production system and the organization of the work.

The choice of model for facility planning used as structural base for this research was made starting from the suitable bibliographical references in courses of production engineering in the national federal universities. The selection was made, in a first moment, with base on the amount of national universities that indicated the same model. The works of Lee (1998) and Tompkins et al. (1996) were drawn in first place with 8% of the indications. The tie-breaker criterion used was the model that was more didactic as for its use. Based on the selection criteria, the work selected was "Facilities and Workplace Design", proposed by Lee (1998).

The model proposed by this research was elaborated starting from the premise that the production engineer can act as responsible for the planning and supervision of the project, being subordinated to the high management, when he can assume technical functions related to the planning of the production system, according to the case; in agreement with the role proposed by Lee (1998) for this professional.

In the model proposed by Lee (1998) the project of facilities is subdivided according to the level of inclusion of the activities in relation to the environment. Each one of these levels includes a group of activities to be accomplished during the elaboration of the project. This form of organization served as structural base for the framing of the demands in the model proposed. The product of the framing between the demand items identified and the structure...
of Lee’s model is represented in the Figure 1.

Figure 1 - Conceptual model proposed for the planning of industrial facilities free from barriers: framing of the demands for inclusion

Figure 2 shows a summary of the conceptual model for the Planning of Industrial Facilities Free from Barriers proposed by this research. The proposed model details for each one of the five levels of the planning the objective, the main activities and the specific tasks to be accomplished in order to obtain an industrial installation free from barriers. Basically, the levels of the model should fulfill the following main activities: i) determining the mission and place of the company considering the advantages and disadvantages of each place under the point of view of the accessibility; ii) elaborating the planning of the place, so that the plant of the land is accessible for its current use and for its future use; iii) defining the layout of the construction, pointing the advantages and disadvantages of each proposal under the point of view of the accessibility; iv) projecting the layout of the departments considering the necessary accessibility demands to the personal space and the communication and; v) projecting the work stations so that they optimize the productivity, be integrated and improve the work experience of those involved.
In the unfolding of each level of the planning the demands are presented to be fulfilled in what refers to the national legislation, the principles of Universal Design and the other complementary information, where the considerations related to the contribution of the case study for the model are included. Figure 3 presents a summary of the tasks and actions to be accomplished in Level I, proposing that the information are collected through check-lists, in order to create a ranking of accessibility for the candidate places, based on punctuations that reflect the importance of each factor to fulfill the strategy of accessibility defined for the new installation.

<table>
<thead>
<tr>
<th>Objective</th>
<th>Demands of Accessibility for Level I of Installation Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identification of accessibility for the location and the impacts for the selection.</td>
<td></td>
</tr>
</tbody>
</table>

**Specific tasks**

1. Obtaining information on accessibility and social inclusion
2. Developing strategy related to accessibility and social inclusion
3. Identifying accessibility for the selected land (places).
4. Evaluating candidates pointing advantages and disadvantages of each place under the point of view of accessibility.

**Actions**

- Determining the mission of the company including: principles of social responsibility that should be adopted, degree of importance of the accessibility for the organization.
- Identifying resources available to invest in diversity in work environment and forms for supporting the inclusion considering the interests of the company.
- The resources should involve: expectation for recruiting of manpower, access infrastructure in the area including: education, transport, culture, leisure, etc.
- The fiscal incentives and legal obligatoriness of the area should be considered.

Figure 3 - Summary of the necessary requirements for Level I of Barrier Free Facility Planning proposed
collected so far to compose a critical analysis of the layouts developed to the selected place, being able to point the advantages and disadvantages for each one of the propositions in relation to the necessary demand items to assist the strategy of defined accessibility in the previous level of the project. The group of requirements that compose the planning of industrial facilities free from barriers for the Level II is presented in Figure 4.

<table>
<thead>
<tr>
<th>Supra Level</th>
<th>Demands of Accessibility for Level II of the Planning of Facilities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Elaborating the planning of the place</td>
</tr>
<tr>
<td>Main Activity</td>
<td>Elaborating the land plant so that it is accessible for current and future use</td>
</tr>
<tr>
<td>Specific Tasks</td>
<td>i. Improving/Confirming the relevant information to guarantee the accessibility.</td>
</tr>
<tr>
<td></td>
<td>ii. Layout with occupation of the land and of the alternative places assisting the accessibility demands.</td>
</tr>
<tr>
<td></td>
<td>iii. Evaluating the layout pointing advantages and disadvantages of each one of the layouts under the point of view of the accessibility.</td>
</tr>
</tbody>
</table>

**Figure 4 - Summary with the necessary requirements for Level II Barrier Free Facility Planning proposed**

In Level III, the planning approaches the interior of the industrial installation, including the analysis of the obligatory accessible routes inside the installation and, in a complementary way, the accessible routes already defined in the previous level. It is suggested that these routes are analyzed as units of space planning. This way, the layouts elaborated will be able to be adapted to the relative minimum demands to the escape routes and the main access to the factory ground, among others. The summary of this level is presented in Figure 5.

<table>
<thead>
<tr>
<th>Macro Level</th>
<th>Demands of Accessibility for Level III of Facility Planning</th>
</tr>
</thead>
<tbody>
<tr>
<td>Objective</td>
<td>Defining the layout of the construction</td>
</tr>
<tr>
<td>Main Activity</td>
<td>Identifying and defining the accessibility demands for the layout of the installation</td>
</tr>
<tr>
<td>Specific tasks</td>
<td>i. Identifying the accessibility demands in relation to the existent physical structure.</td>
</tr>
<tr>
<td></td>
<td>ii. Identifying the accessibility demands in terms of obligatory accessible routes (emergency exits, main entrance, access to the factory ground, etc.) or desirable (alternative or complementary routes).</td>
</tr>
<tr>
<td></td>
<td>iii. Calculating space considering the accessibility parameters.</td>
</tr>
<tr>
<td></td>
<td>iv. Identifying limitations as for the accessibility demands.</td>
</tr>
<tr>
<td></td>
<td>v. Generating options of space planning considering the accessibility demands (obligatory routes, desirable routes, etc.).</td>
</tr>
<tr>
<td></td>
<td>vi. Analyzing the options of space planning pointing the advantages and disadvantages of each layout under the point of view of accessibility.</td>
</tr>
</tbody>
</table>

**Figure 5 - Summary with the necessary requirements at Level III Barrier Free Facility Planning proposed**
The demands identified in the previous level can be detailed in Level IV (Figure 6), in order to elaborate the layouts of the departments considering the accessibility demands. This level suggests the elaboration of a structured recruitment, selection, hiring and development (permanence and promotion) program for disabled people. To make the inclusion of people with different cognitive deficits viable, or even to accommodate different needs and/or unexpected contretemps of the employees, there is a proposal of conformability of the elements of the production system as a basic requirement for the success of the inclusion, among which the production rhythm is mentioned. A flexible rhythm can make possible the gradual transfer of the work to the employee, respecting different variations in the form and necessary time for learning; what would not be possible with a fixed rhythm of production determined by a conveyor.

### Micro Level

**Demands of Accessibility for Level IV of Facility Planning**

<table>
<thead>
<tr>
<th>Objective</th>
<th>Projecting the layout of the departments to guarantee a calm flow of work, promoting teamwork.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Activity</td>
<td>Elaborating the layouts of the departments considering the accessibility demands necessary for the personal space and the communication.</td>
</tr>
</tbody>
</table>
| Specific tasks | i. Selecting products and processes taking into account the accessibility demands.  
   ii. Projecting layouts of cells taking into account the accessibility demands.  
   iii. Evaluating the layout options pointing the advantages and disadvantages under the point of view of the accessibility. |
| Actions | • Identifying the necessary accessibility demands to the layout project of the departments to allow a work flow the most accessible as possible.  
   • Analyzing the processes and planning of operations to consider the demands of accessibilities. |

**Figure 6 - Summary of the necessary requirements for Level IV of Barrier Free Facility Planning proposed**

Level V, the last one of the planning, seeks to conceive an accessible, productive, comfortable and safe work environment, taking into account the legislation of effective accessibility. It intends to look for the maximization of the results without making the accessibility unfeasible and generating the most accessible workstations possible, without compromising the effectiveness of the work environment. Figure 7 presents a summary of this level.

### Sub-micro Level

**Demands of Accessibility for Level V of Facility Planning**

<table>
<thead>
<tr>
<th>Objective</th>
<th>Projecting the work stations so that they optimize the productivity, integrating and improving the experience of work of those involved.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Main Activity</td>
<td>Elaborating the project of the work stations, considering that at least 5% of the workstations should be accessible.</td>
</tr>
</tbody>
</table>
| Specific tasks | i. Identifying the applicable accessibility demands at this level.  
   ii. Conceiving the layout options considering, for all the items, the accessibility demands: reach frequencies; weights; handling and other factors.  
   iii. Identifying the limitations under the point of view of the accessibility;  
   iv. Generating options of space planning considering the accessibility demands.  
   v. Evaluating the options of space planning pointing the advantages and of each project under the point of view of the accessibility. |
| Actions | • Projecting seeking an environment of work accessible, productive, comfortable and safe, |
taking into account the legislation of effective accessibility.

- Maximizing the results without making the accessibility unfeasible.
- The areas that offer the necessary knowledge on the project of the work stations should be analyzed, observing the possibilities to generate the possible maximum of accessible workstations, without compromising the effectiveness of the work environment.

Figure 7 - Summary of the necessary requirements for Level V of Barrier Free Facility Planning proposed

5. Final considerations

A structured group of recommendations was developed to reach the main objective of this research, it was developed seeking to contribute with the suppression or minimization the different forms of barriers that can be identified along the stage of planning of industrial facilities, so that the result is accessible for the people with disabilities or reduced mobility.

“Conceptual Model for the Planning of Industrial Facilities Free from Barriers” was the name attributed to this solution.

In the case of the demands related to the interior of the company, it approaches much more than the elimination of architectural barriers and prevention of risk factors related to health and safety at work, approaching even the need of involvement and effective commitment of the management, as well as the involvement of the employees. In special cases it is suggested the need of adjusting parts of the tasks that the worker cannot accomplish, or even the conformability work schedules to make possible the accomplishment of tasks by employees with disabilities.

The proposed model was developed using as structural base the model for planning of facilities proposed by Lee (1998). The demands for inclusion identified by the research were organized taxonomically in agreement with this structure. The demands of the proposed model could be validated through a case study accomplished in an industry that works with disabled people in the factory ground.

The fact is that the theme approached by the present study has been getting more and more national as international representativeness and projection. With this, the proposed model intends to discuss that integrative solutions can be used in the formation of the future production engineers, to facilitate their performance in the conception of industrial facilities free from barriers, making the environment of industrial work accessible for people with disabilities or of reduced mobility; contributing for the fulfillment of the crescent and necessary demand for those individuals’ social inclusion and, as consequence, supporting the social responsibility of the new installation.

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