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COMFORT SEAT MODULE - FIRST CLASS COMFORT FOR ALL

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ABSTRACT

The Comfort Seat Module (CSM) is a project developed in the scope of the EDAM focus area of the MIT – Portugal program, within the Product Design and Development course.

The team members involved in the project come from several Engineering backgrounds and includes research students and engineering professionals, from different geographical origins.

In this project the team had the purpose of designing and developing a solution, from idea into concept and then onto a valid product that could potentially be produced and even marketed. In parallel, the objective was to train the product development competences and team's working skills as much as possible, considering the physical distance between the team members.

KEYWORDS: Customer needs, head, neck, comfort, product design and development

1. OBJECTIVES

The first aim of this project was to identify an unsatisfied market need, and suggest a possible product solution that permitted the project team to develop it, going through all phases of the product's design and development.

After identifying the market need for which the customers felt unsatisfied, the team proposed to develop a product that would increase the travelling comfort, in any seat, economy or first class. The product was intended to provide an adequate posture, including support for the passenger's head and neck, at a more competitive price than current solutions.

In section 2, it is described the team work process throughout the whole project, until the final project presentation.

Section 3 presents the methods that were used for the users' needs identification, in order to find the unsatisfied market demands.

The phases of product design and development are detailed in section 4, from the initial technical specifications definition, screening and scoring processes for concept's choice, final concept's evaluation, and its detailed specification for the prototype's manufacturing.

Finally, in section 5 are summarized the main achievements and conclusions, as well as future research possibilities for the CSM.

2. TEAM WORK DESCRIPTION

The team members were inscribed in three different Portuguese Universities, which are located in different cities, two in the north and the other, in the capital, in the center of the country. The time that the members spent together was only during classes (3 periods of 2 consecutive weeks between September 2007 and January 2008), which was considerably short for the amount of work that had to be accomplished.

Therefore, during the remaining periods the work was divided in some clear milestones to reach, based in the Design and Development phases proposed in Ulrich and Eppinger's book [1]. For each milestone, the team made a first virtual meeting, in order to start doing some brainstorming and during which each of the members could express his individual opinions (and interests) to the group in order to achieve the team's common goal. For each milestone, it was defined a different team leader, who was in charge of coordinating the team work and of delivering the weekly assignment.

Following the first meeting, there were usually necessary other ones, at least once a week, in order to discuss the progress status of the work. For those meetings it was used a free software that it made possible to have long teleconferences with a low cost.

Some of the team members, who belonged to the same university, had the opportunity to meet more frequently. After those meetings, a short report was sent to update the other members.

Concerning the individual work of each member (hand drawings, ideas, reports), it also had to be distributed to the others using a digital support. The team even tried to use collaborating software that allows sharing previously uploaded documents between groups, but it wasn't yet very efficient to use since it didn't work correctly when two persons were changing the same document. Instead of that, it was used a common template, with the different sections attributed to each member, to write his individual work. After that, each part was sent via e-mail to the assignment leader in charge, who also had the task of completing the report and of guaranteeing the inclusion of each section.

During classes' days, the team used all the available free time to meet and discuss the project's progress using other kind of tools, like whiteboards and mock-ups to share the group's ideas. With such high commitment, the team members were able to manufacture two functional prototypes during one of those classes' periods.

By the end of the project, it was consensual that the CSM was surely a better product because of the team work accomplished. It was found that effective and efficient teamwork goes beyond individual accomplishments. The most complete teamwork is produced when all the individuals join their contributions and work towards the same objectives. Therefore, the work was distributed according to the skills of each team member.

3. USERS' NEEDS IDENTIFICATION

"The customer is always right" is a well known sentence.

"It all starts with the customer, and it is the customer, not the organization, who defines quality and value", [2] could be another motto for any kind of organization.

"Guestology" is a term introduced by Ford et al. and involves systematically searching for the key factors that determine quality and value in the eyes of the guest (i.e. customer). That includes modeling those key factors for study, measuring their impact on the customer experience, testing various strategies that might improve the quality of that experience, and then providing the combination of factors or elements that attracts customers and keeps them coming back.

Therefore the identification of the user needs was considered critical to the design and development of the CSM. In order to obtain them, the design team opted for a triple strategy: observation of public transportation users, indirect contact with users through a questionnaire and direct contact performing individual interviews.

3.1.Observation

As some researchers argue, it is very difficult to obtain customers' latent and subjective needs by simple asking them [3, 4]. So, observation of passengers using their seats was also performed, to notice their activities or the difficulties faced.

As it was mentioned in section 2, using the available time to complete this specific assignment, the team members decided to observe people seating for journeys around 1 hour long in several means of public transportation like buses and trains. The observations were made concerning the behavior of passengers while seating, both when awake

and when sleeping, to understand if changes in body position were frequent or not, and which kinds of interactions existed with the seats (e.g. if people leaned the seats often or not, if they tried to change the head support position and other).

3.2.Questionnaire

A questionnaire was developed to target mainly the users of seats in medium and long distance commercial travelling over 2 hours long, composed of a set of questions. This method was intended to reach a great number of users in the short time available for this task, using the team's network connections and the ease of dissemination of the questionnaire by digital means. Overall, the team was able to compile valid data from a total of 52 male and female users of different age groups, as is summarized in Table 1.

Table 1– Number of responses to questionnaire

Age group	Female	Male
< 18	-	2
18 – 30	15	19
31 – 50	4	6
> 51	2	4
Total	**21**	**31**

The questionnaire included a total of nine questions, two of them were control questions, to identify respondents that were in fact users of seats in medium and long distance travelling, and the remaining were questions aimed at interpreting the needs of those users. Given the low participation of people to these kinds of surveys, a very limited number of questions were designed. Eight of those questions had predefined options and only one previewed a free answer.

The results obtained from the questionnaires showed very clearly that the outstanding majority of people sleep when travelling for more than 2 hours, which reveals that the body is more relaxed and thus requires further support to provide comfort.

The results presented in Figure 1 also show that a large majority of people have difficulties to find a comfortable seating position. They also show that the neck is the body part, and the bus is the vehicle in which people feel more discomfort.

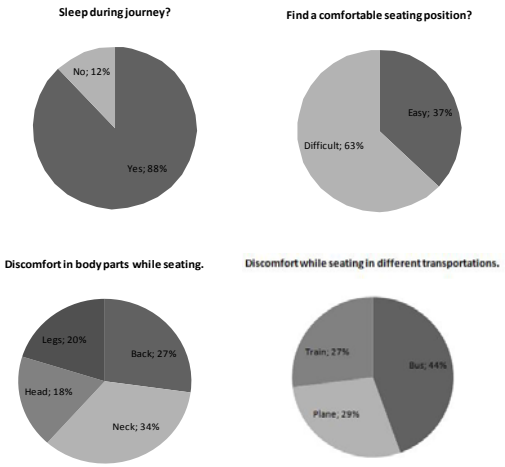


Figure 1 – Results from questionnaire

In general, the results from the questionnaire survey indicated there was a considerable margin for improvement in terms of seat comfort, especially concerning the comfort of the head and neck.

3.3.Interview

In order to get more detailed feedback, the team also focused its efforts in doing a number of personal interviews to seat users in medium and long distance travelling. In this process, a guideline of subjects to be addressed was defined by the team that concerned the perceived comfort of users while seating during a journey of more than 2 hours and also the characteristics of seats, or other, that could be associated with it.

For this assignment the team had only a period of 2 weeks, during which, a total of 24 interviews were conducted on people of all genders and different age groups, as presented in Table 2. In particular, the feedback obtained from professional users of an airline company were considered very relevant, because they were considered as Lead users, since their "needs will only become general in a marketplace months or years in the future" [5].

Table 2– Number of individual interviews

Age group	Female	Male
< 18	-	1
18 – 30	5	7
31 – 50	3	3
> 51	3	2
Total	**11**	**13**

Interviews are very personal, and opinions given by the interviewees are highly subjective.

Although this is a more direct method of gathering information from users, the process itself requires considerable experience of the interviewer in order to extract the most objective information possible, without influencing in any way the responses of the interviewee.

The team completed the round of interviews which led to a long list of statements made by the interviewees. From these, the team implemented the methodology of interpretation of needs (Ulrich and Eppinger's [1] to organize them hierarchically.

3.4.Needs' hierarchical organization

Taking the previous information in consideration, the customers' needs were listed in hierarchical levels, and translated into technical specifications using Ulrich and Eppinger's [1] method.

Table 3– Customer needs organized hierarchically and attributed level of importance

Primary needs	Secondary needs	Tertiary needs	Level of importance (see Note)
Body support	Lateral support	Head support	1
		Neck support	1
		Back support	3
	Arms support	Independent armrest	2
	Vertical support	Legs support	3
		Feet support	3
Solo entertainment	Support for food/beverage		3
	Play games		4
	Play music		4
	Watch scenery	Pilot vision	3
	Hear music	Independent	2
	Watch movies/TV	Independent	2
	Accessing internet		3
	Adequate lighting		2*
	Support for PC		3
Social entertainment	Talk to others		2
	Move around		2
	Play games	Interactive activities	4
	Play music		4
Privacy	Space	Aisle (corridor)	2
		Seats-lateral	2
		Seats front-rear	2
	Silence		3*

Note: Level of importance: 1 – critical, 2 – very important, 3 – important, 4 – significant, 5 – neutral); Latent needs are identified with *

The identified needs were split in primary, secondary and tertiary needs, and then weighted in respect to their relative importance to the users. The results are shown in Table 3.

From the identified and organized user needs, the definition of specifications was done afterwards, which initiated the process of design and development of the product. Further detail is given in the next section.

4. PRODUCT DESIGN AND DEVELOPMENT

Following the identification of the users' needs it was concluded that buses are the transportation vehicles in which people have a higher discomfort level, the seats do not give enough support and the head and neck are the body parts in which travelers feel more discomfort. Therefore, the CSM was developed as an accessory based in the bus' seats characteristics (i.e. high seats that already incorporate a headrest), and the head and neck lateral support were considered as critical needs (i.e. due to not only their level of relative importance, but also to gathering of particular needs from the bus companies, seats' manufacturers and general regulations), as can be seen in Table 3.

4.1.Technical specifications

After the contact with the customers, their needs were translated into specifications, assuring that each was defined in a way that allowed a better definition of product characteristics. After listing the critical needs they were compared with a list of metrics, to guarantee that all would be technically defined and measurable by clear specifications. In this stage, the information from previous competitive analysis was valuable because allowed comparisons to other products and their performance.

The critical specifications that were defined for the CSM were:

- contact area with the head and neck;
- ergonomics;
- vertical and horizontal adjustment for better head support;
- compatibility with seat / modularity;
- competitive manufacturing cost and selling price.

4.2.CONCEPT'S SCREENING AND SCORING

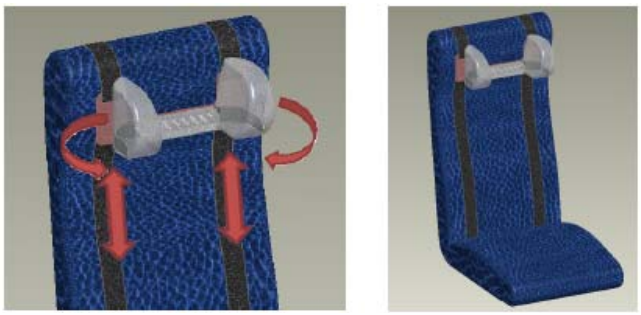
Eleven sketches were drawn, and afterwards selected based on screening and scoring matrixes [1]. The screening matrix has the main objective of eliminating the concepts that are worse that the selected reference. All of the suggested concepts have passed the screening process, considering the fact that the reference to which they were compared, was the headrest integrated in common bus seats. Initially the team has also chosen other existent accessories for individual comfort as a reference, but the conclusions were that all the proposed concepts were clearly better.

The next step, the scoring matrix, consists of a quantitative evaluation (as opposed to the qualitative screening) of each concept. For the quantification, the weights of the selection criteria are chosen according to their relative importance in the final product. So, the head support, and the vertical and horizontal adjustments were defined as the most weighted criteria, since these are the structures and systems that were proposed to improve comfort.

Each concept was then evaluated, and the one that reached the best scoring underwent further improvements in some features as head and neck support structure as well as the possibility of a horizontal adjustment. From these improvements, the final concept was sketched.

4.3.FINAL CONCEPT DEVELOPMENT

The proposed final concept (see Figure 2) consists in a head and neck support accessory applied to passenger seats in buses for medium to long course travelling.



A **B**

Figure 2 - 3D concept. A) Scheme identifying possible directions of adjustment. B) Isometric view;

In terms of functionality, the "comfort cushion" should guarantee, as the name already indicates, the comfort role. Regarding adaptability to the users' head and neck, it is assured by the "frame structure" (mounted in the cushion interior) which has to be made of a material that permits the user to adjust it to his/ her desire and after that maintain the chosen position. To guarantee a good neck support to the user, the cushion also has a middle section that connects its lateral sections. The full system integration to the sliding belts, that are previous assembled in the bus seat, is accomplished passing them through an open area existing in the support cushion part. On the other hand, the assemblage of the three main parts, that is, "support cushion" / "comfort cushion" with "frame structure" is accomplished by means of rivets. These are mounted in the middle back area of the "support cushion" part. This process is well illustrated in Figure 3.

To permit the vertical adjustment of the CSM, the belts slide through the upper rectangular holes in the support cushion (see Figure 3). To fix it vertically, two Velcro rectangles (see Figure 3) are used to create a strong adherence to the belts. In Figure 4 is exemplified the concept's adjustment.

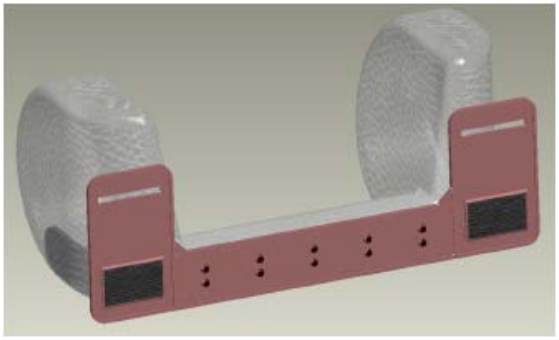


Figure 3 - Illustration of the assembly of the three main parts.

Figure 4 - Concept functioning.

In order to dimension correctly the overall system, it was introduced a dummy's assembly (percentile 96) in the 3D CAD software. Thus, in Figure 5 it is represented a picture of this assembly which allowed to make a first product validation in terms of dimensions.

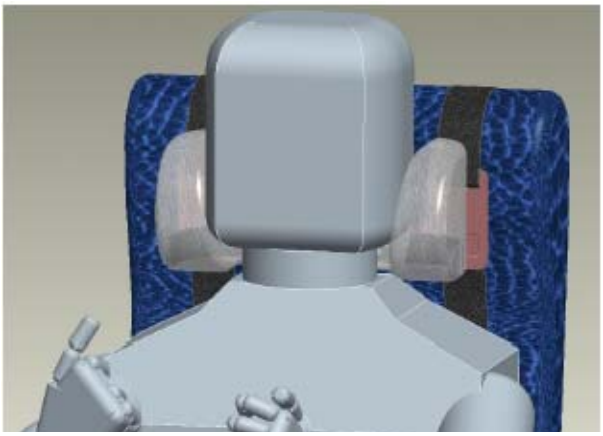


Figure 5 - Global integration of CSM with Dummy.

4.4.Concept's Evaluation

With the final concept defined, it was performed a market survey. With this survey, it was intended to present the concept's images to potential customers, and obtain feedback regarding the project's goals, in order to redesign the concept according to the potential customers' opinion.

The data showed that 95 % of the respondents have felt uncomfortable to rest or sleep during their travels. It was over this group of persons that more attention was focused, since they revealed a need for a product like the CSM and might provide valuable feedback in order to improve it.

When they were asked if they would see the CSM as useful to enhance comfort and travel experience, the answers were 100 % positive. All of them confirmed that would like use the CSM in their trips. This approval, like in the first survey when scanning the user's needs, revealed the necessity of a better travel comfort and confirmed a lack in the seats' market.

In terms of utilization of the product, 96 % of the respondents affirmed that they would like to use it, and travel in buses with this kind of system. Some of them, 4 %, did not show such enthusiasm, what may represent some apprehension in some issues like effectiveness, safety or hygiene of the product.

To summarize the evaluation, the respondents were asked to evaluate qualitatively the final concept. As can be seen in Figure 6, the majority said that it would perform well, and 22% declared that it was exactly what was missing. No one said that the product was inappropriate and that would not represent any added value to the journey.

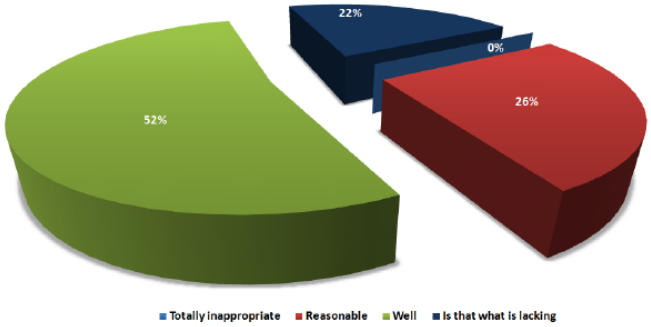


Figure 6 - Evaluation of the final concept.

4.5.Product Architecture

In the previous section it was shown the feedback obtained from the possible users of the product. With their comments, individual parts of the prototype suffered some improvements.

As an example of one of those parts, the "comfort cushion", it was one of the most important and carefully revised parts. Basically, the cushion is the section that is in contact with the head for a comfortable support with lateral supports for the head and a middle section for the neck, constituting a single body piece.

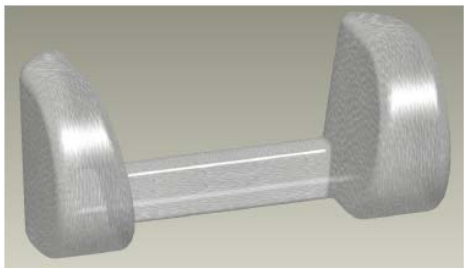


Figure 7 - Illustration of the Cushion Structure

For this body part it was desired good ergonomic surface and also a system to be able to adjust the cushion's lateral parts. The structure with those two lateral wings was changed to help the comfort satisfaction by providing a resting place for the head, eliminating this way the discomfort position of the head when there is no structure to lay it down. Another

configuration to enhance the comfort is the “U” shape of the cushion, giving also support for the neck in the middle section.

The main bottleneck in the project was the definition of the lateral parts’ adjustment system, and for this it was decided to choose a simple mechanism, like an internal frame. This frame is able to bend with the force of the users and at the same time to sustain the weight of the head when it is leaned to the lateral sections.

The hygiene is another important issue in the cushion, and for that, the product takes a protective layer that can be changed, in order to wash it and use it again. It is important to see that transportation, nowadays, requires comfort, durability, safety and a competitive price.

Basically, the cushion structure was defined as an assembly of three mentioned structures: the frame, the foam and the protective layer. It is possible to see in Figure 8, the disposition of these three layers, in a cross section scheme.

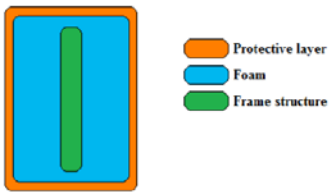


Figure 8 – Cross section view of the cushion structure

4.6.Material and Technology Selection

In this section it is intend to explain, for each component and for each characteristic of the component, which is the best material in terms of application and also business profit.

The “support cushion” part is to support the cushion and slide up and down along the belts. It is important that this structure has some rigidity in its middle area and at the same time some flexibility in its extremities so these sections adapt to the back of the seat. A material family that provides such behavior is the thermoplastics polymers. Also the shape of the structure presents some ribs in the middle area in order to give more rigidity to it. Since this product is for automotive industry, safety is an important issue and therefore attention to the flammability was taken in consideration. According to these previous parameters, Polypropylene was the choice. Basically is one of the most versatile polymers, and with low density, high softening point, high rigidity and hardness.

As it was mentioned, the cushion structure has the main goal to provide a comfortable support to the head. It is the section that sustains the head for a comfortable support with lateral portions for the head and a middle section for the neck, building a unique body piece. In the previous section, it was shown a cross-section view (Figure 8) of the cushion, with three different materials with three different purposes. Particularly for the foam, to provide the best comfort and ergonomics possible the choice was flexible polyurethane foam, which is a large family of polymers with widely ranging properties.

The inner “frame structure” is intended to provide rigidity, so it can support the head and neck’s weight, while at the same time, being flexible enough to be adjustable by the passenger. It is a tricky compromise, that has to be achieved both through the selection of an appropriate material and the definition of an adequate shape for the frame structure. In the prototype, the team decided to use an aluminum alloy with high fatigue resistance.

Finally, the fabric layer also needed to be defined to cover the foam, to ensure the cushion’s hygiene. The idea is to have a removable layer that is capable of being washed and switched during the life of the product. In terms of material, the choice for this case is very simple, cotton or leather.

4.7.FINAL PROTOTYPE

The selected and improved concept was manufactured using the technical specifications and with the aid of a seats’ manufacturer. Since the prototype presented in

Figure 9 was made in only one unit, its manufacturing was essentially handmade work. Nevertheless, it served to validate the CSM’s design and development process, and it was tested by the team members and teachers.

Figure 9 – Final prototype

5. CONCLUSIONS AND FUTURE RESEARCH

After the first contact with the customers, it could be concluded that the existing products did not address adequately to the user needs. Most solutions in the market did not offer the proper body adjustment for passengers with different body structures.

Therefore, the team used different strategies to identify the users and customers needs regarding passenger seats used in long course travelling. Considering the time frame available, it was considered an achievement to be able to contact several dozen people that answered to the questionnaires and participated in the individual interviews. From this process, the team was able to capture the most relevant needs from lead and regular users and also from potential customers, such as transport providers and seat manufacturers. In this respect, the team was aware that the interactions with users and customers should be maintained throughout all the project development's phases.

The concept development is a crucial activity that usually takes long time in industry. Considering the available time, the team put the effort to develop as many concepts as it could to foster the collaboration of each member and to obtain relevant product concepts. This way, each member tried to develop the concepts simultaneously with the other tasks, having the need to permanently reevaluate and in turn improve them.

The hurdle that the team had to overcome in this project was the definition of a solution – shape, material and technology – for the "shape frame". This decision was a bottleneck from the project's point of view, because other activities were dependent from it, like the complete bill of materials and also the final version of the drawing for that body part. Once the team was confident enough to decide on a solution for it, and after performing some experimental tests, it was possible to conclude all the drawings and complete the bill of materials. More recently, one of the members performed a literature review to analyze the possibility of using a shape-memory alloy (SMA) [6, 7] because of its theoretical higher mechanical fatigue resistance, when compared to other metals. It was considered that a SMA would perform technically better than another solution, even though it is considered relatively more expensive. Nevertheless, taking in consideration the increase in the expected life of the part, it would benefit the application in the long term.

The team has also established contacts with the staff from a bus company that provides transportation in medium to long course range, who have suggested that, in their opinion, buses have more capacity for improvement than other public transportation vehicles.

Although the team chose to use a bus' seat as the platform for the CSM's development and manufacturing, all the technical specifications were defined in a way that allows its adaptation to other types of seats.

The CSM has revealed high market relevance, based on the opinion of its potential users, obtained from the concept's questionnaire. After the final prototype's manufacturing, the team had not the opportunity to test it with users in real bus trips. Therefore, the engagement of one of the team members in a research project that intends to increase the travel experience in buses, reveals a very good opportunity to test the prototype with passengers, and to further validate the CSM. Within this research project, it is intended to perform a survey to a large sample of passengers (e.g. 500), what may be used to statistically approve the comfort accessory proposed.

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REFERENCES

1. Ulrich, K.T. and S.D. Eppinger, *Product design and development*. 3rd ed. 2004, Boston: McGraw-Hill/Irwin. xviii, 366 p.
2. Ford, R.C., C.P. Heaton, and S.W. Brown, *Delivering Excellent Service: Lessons from*

the Best Firms. California management review, 2001. **44**(1): p. 39.
3. Dahan, E. and J.R. Hauser, *Product Development - Managing a Dispersed Process*, in *Handbook of Marketing*, B.W.a.R. Wensley, Editor. 2001.
4. Kristensson, P., *Managing Ideas That are Unthinkable in Advance: A Matter of How and Where You Ask*, in *Involving Customers in New Service Development*, B. Edvardsson, et al., Editors. 2006, Imperial College Press. p. 127-142.
5. von Hippel, E., *Lead Users: A Source of Novel Product Concepts.* MANAGEMENT SCIENCE, 1986. **32**(7): p. 791-805.
6. Humbeeck, J.V. and R. Stalmans, *Shape Memory Alloys, Types and Functionalities*, in *Encyclopedia of Smart Materials*, M. Schwartz, Editor. p. 951 – 964.
7. Bernardini, D. and T.J. Pence, *Shape-Memory Materials, Modeling*, in *Encyclopedia of Smart Materials*, M. Schwartz, Editor. p. 964 – 980.