

This entry received a **score of 5** from two expert raters using the EDPPSR. Each found the problem to have been clearly and objectively identified and well elaborated (although the actual problem statement does not appear until the very end of the entry, when the students note, “The problem is therefore very clear: the people who use current walk-assist devices often do so with poor posture and impeded gait, and may experience further injury.” The justification of the problem (framed as a market analysis) highlighted the concerns of various primary stakeholders (the elderly, their social workers and care givers, and insurers, among them) and is based on extensive consistently credible sources, including publications such as the biomedical journals and interviews with health care professionals. One rater noted that sources, while identified, are not accompanied by detailed citations, making it hard to always ascertain timeliness. It is possible that a bibliography or reference section was intended but not completed, or was prepared but not included as part of the e-portfolio. Its absence does not provide sufficient cause to lower the score for this comprehensive entry. Multiple measurable design requirements can clearly be determined based on the detail in the problem justification in this entry.

#### Engineering Design Process Portfolio Scoring Rubric Component and Element Titles

##### Component I: Presenting and Justifying a Problem and Solution Requirements

- **Element A: Presentation and justification of the problem**
- Element B. Documentation and analysis of prior solution attempts
- Element C. Presentation and justification of solution design requirements

##### Component II: Generating and Defending an Original Solution

- Element D: Design concept generation, analysis, and selection
- Element E: Application of STEM principles and practices
- Element F: Consideration of design viability

##### Component III: Constructing and Testing a Prototype

- *Element G: Construction of a testable prototype*
- Element H: Prototype testing and data collection plan
- Element I: Testing, data collection and analysis

##### Component IV: Evaluation, Reflection, and Recommendations

- Element J: Documentation of external evaluation
- *Element K: Reflection on the design project*
- Element L: Presentation of designer’s recommendations

##### Component V: Documenting and Presenting the Project

- Element M: Presentation of the project portfolio
- Element N: Writing like an Engineer

**Please Note: Elements M and N require no submission from the portfolio author(s) and are intended to be scored based on the portfolio work as a whole from what has been submitted from Elements A through L**

## ***Element A: Presentation and justification of the problem***

- 5** The problem is clearly and objectively identified and defined with considerable depth, and it is well elaborated with specific detail; the justification of the problem highlights the concerns of many primary stakeholders and is based on comprehensive, timely, and consistently credible sources; it offers consistently objective detail from which multiple measurable design requirements can be determined.
- 4** The problem is clearly and objectively identified and defined with some depth, and it is generally elaborated with specific detail; the justification of the problem highlights the concerns of some primary stakeholders and is based on various timely and generally credible sources; it offers generally objective detail from which multiple measurable design requirements can be determined.
- 3** The problem is somewhat clearly and objectively identified and defined with adequate depth, and it is sometimes elaborated with specific detail, although some information intended as elaboration may be imprecise or general; the justification of the problem highlights the concerns of at least a few primary stakeholders and is based on at least a few sources which are timely and credible; although not all information included may be objective, the justification of the problem offers enough objective detail to allow at least a few measurable design requirements to be determined.
- 2** The problem is identified only somewhat clearly and/or objectively and defined in a manner that is somewhat superficial and/or minimally elaborated with specific detail; the justification of the problem highlights the concerns of only one or two primary stakeholders and/or may be based on insufficient sources or ones that are outdated or of dubious credibility; although little information included is objective, the justification of the problem offers enough objective detail to allow at least a few design requirements to be determined; however, these may not be ones that are measurable.
- 1** The identification and/or definition of the problem is unclear, is unelaborated, and/or is clearly subjective; any intended justification of the problem does not highlight the concerns of any primary stakeholders and/or is based on sources that are overly general, outdated, and/or of dubious credibility; information included is insufficient to allow for the determination any measurable design requirements.
- 0** The identification and/or definition of the problem are missing OR cannot be inferred from information included. A justification of the problem is missing, cannot be inferred from information included as evidence, OR is essentially only the opinion of the researcher.

## I. Executive Summary

Many aging adults find that they need to use mobility-assisting devices in their everyday lives. The type of mobility-assisting device the user requires depends on several factors, such as age, balance, and mobility-level. For those who are relatively mobile, a cane may suffice, while adults with greater mobility limitations may need to utilize walkers or even wheelchairs.

Each member of the team has observed elderly persons using mobility-assisting devices. Whether it was through observing a direct family member, a patron in a retirement home, or members of the general public in their day-to-day life, each member of the team felt there was a need in the market for a product that would promote a better way of living for those who require mobility-assisting devices.

The focus of the team's project is the market for user with mobility that requires more assistance than a cane, but less assistance than a walker. After interviewing Mrs. Ellen Exelbert, a user of mobility-assisting devices who is interested in sponsoring the project, the team discovered that there is a large gap in the market between canes and walkers. The interview gave the team primary insight into the customer requirements towards walking aids that fit in this gap. For example, the ability to fit on a step as the user climbs a staircase is a customer requirement that is not considered for traditional walkers.

The team has found through market research and interviews that although current walkers are viable solutions to mobility problems and are used by many, the current walkers' ability to provide their users with improved posture, gait, mobility, and balance is not fully realized. Through user error, poor design, or a combination of these two factors and others, many walker users deal with decreases in posture, gait, and mobility, and a consequent increase in dependency on their device. During the development of new concepts and solutions, the team's focus for each design was to improve current walker users' posture, gait, comfort, stability, and maneuverability.

The overall goal for this project was to develop a product that promotes good posture and natural gait, while providing stability and maneuverability comparable to current products on the market. The new device was designed to both function well and be visually appealing, along with being easily portable. This report takes the reader through each step of the product development process as it applies to the group's new walk-assist device, Ergo-Couture. From problem identification and market analysis, to concept generation and selection, and finally through fabrication, testing, and cost calculations, the team has designed a product to meet the needs of the elderly with limited mobility.

## II. Market Analysis Information

### II.1 General Need for Product

Products are developed in response to needs of end users for improved interaction with their environment in order to perform a task.

Older adults often rely on aids for stability and balance while walking. In 1994, 3.15 million older Americans reported that they used canes and 1.4 million older Americans reported that they used walkers for assistance while walking (Stephens, 1). “Loss of confidence [in walking] and deteriorating balance” are the most common reasons why elderly individuals use walkers (BMJ, 925). Therefore, it would seem as if the use of walkers would help elderly individuals cope with their decreasing mobility as they age; however, walkers and other walking aids are often harmful to their users.

A study conducted by the National Center for Injury Prevention and Control estimates that 47,312 older adult fall injuries associated with walking aids occur annually (Stephens, 1). Of these fall-related injuries, 87.3 percent occur while using walkers and 12.3 percent occur while using canes (Stephens, 1). Even more concerning is the fact that 33 percent of walker injuries required hospitalization (Stephens, 3). A study conducted at a nursing home in British Columbia found that “20 percent of falls occur while the patient [is] using a walker or wheelchair” (Stoller-Conrad, 1). The use of walking aids impedes the natural gait of users and causes them to “trip” on their walkers or canes. This fact is especially true in elderly who suffer from diabetes or hemiparesis, as these two conditions can cause elderly individuals to lose feeling in and control of their feet.

An experiment conducted by R Anslow, LL Pinnington, DJ Pratt, J Spicer, CD Ward, and N Weyman studied the maneuverability of walkers by watching participants complete an obstacle course filled with challenges that elderly individuals face in their everyday lives while using a walker. The report claims that “potential safety problems were observed in 87 out of 96 trials” (Anslow, 1). The report goes on to say that most of the safety issues dealt with mobility around obstacles. This lack of mobility can also be attributed to the fact that walking frames “severely restrict walking speed” and often result in “discontinuous gait” (BMJ, 925)(Judge, 1).



**Figure II.1.1:** Falls with walkers occur when users try to navigate around obstacles (such as the tree or uneven ground in the left image) or when users trip over their walkers and fall forward (as in the image to the right).

In addition to falls and safety issues due to impaired gait, walker users often develop muscle or skeletal injuries due to the stress of using walkers. The design team

interviewed a former social worker, Deborah Catherine, of the Asbury Methodist Village in Gaithersburg, Maryland, who worked with Alzheimer’s patients for over five years. Catherine stated that elderly residents often “leaned on their walkers too much,” causing poor posture and increased stress on their upper body. While walkers are supposed to be used for maintaining balance and providing extra stability, users who place too much of their weight on their walkers can suffer from wrist, arm, and shoulder injuries. This statement is echoed by a report in the British Medical Journal which details case studies of elderly women who used walking frames. One woman experienced “increasing difficulty using her hands since walking with a frame,” which doctors later attributed to the development of ulnar nerve palsy (Br Med J, 778). The report goes on to state that ulnar nerve palsy can develop from “chronic pressure from a walking frame” (Br Med J, 778). Of the 30 individuals who participated in the study conducted by Anslow, Pinnington, Pratt, Spicer, Ward, and Weyman, 22 experienced pain while using a walking frame (Anslow, 1).

The increase of stress on the upper body of users often results from poor posture and lack of proper education. In her interview, Catherine stated that elderly users often have poor posture while using walkers because the walkers are “not at the correct height or [they] walk too far back from [their] walkers.” Catherine says that this results in a “hunched” position that is harmful to the users’ backs and shoulders. Poor posture can be remediated by properly educating the user. Approximately two-thirds of walker users report problems with their current walkers, and experts estimate that 56 percent of these problems stem from the user using the walker in a dangerous or improper fashion (Mann, 1). Elderly individuals should therefore receive “professional assessment, prescription, and follow-up” when purchasing a walker (Mann, 1). Catherine also reports that walkers are positioned at the incorrect height due to users purchasing a walker without discussing its use with a doctor.



**Figure II.1.2:** Elderly users hold their walkers too far in front of them, resulting in hunched posture.

The physical injuries, unnatural gait, and poor posture that elderly individuals develop while using walkers can add to their deteriorating mobility due to other ailments. For example, individuals suffering from Parkinson’s disease, arthritis, or a stroke may experience additional pain due to a hunched posture and stress on the upper body.

These added stresses makes coping with other ailments even more difficult. The development of poor posture and restricted gait also means that users often become reliant on their walkers. Once users begin to use a walker, they will often never be able to return to walking unassisted and may lose their independence completely.

Elderly users often believe that walkers or assistive devices are associated with the stigma of being dependent on others; and this discourages them from using their walking aids in public situations. When in front of others, elderly who otherwise need a walker or cane to walk will try to walk without their aid in order to seem independent. A study conducted by Rachael Goberman-Hill and Shah Ebrahim states that “the meanings that people attribute to [walking] aids are important because they effect whether aids will be used or not” (Goberman-Hill, 1). Elderly individuals in this study admitted that they resist using canes or walkers because they do not want to be seen as old. One participant says, “[not using a walking stick] is due to...pride I suppose,” and a second participant states, “I’m annoyed I have to [use a walking stick]. It suddenly marks you down straight away as an old so and so” (Goberman-Hill, 1).

This negative view of walking aids was reinforced by an interview with Mrs. Ellen Exelbert, a retiree in Easton, Maryland, who requires a walking aid. Mrs. Exelbert walks using a cane and a rolling suitcase because she does not want to appear old or incapable. To her, using a walker damages others’ perceptions of her, and she does not want to use any device that looks like a traditional walking aid. Therefore, there seems to be a market need for a product that is aesthetically pleasing to elderly users and provides support as well as (or better than) a traditional walker.



**Figure II.1.3:** Elderly users may resist using walkers in public because they do not want to feel “old.” This mentality can lead to falls and additional injuries.

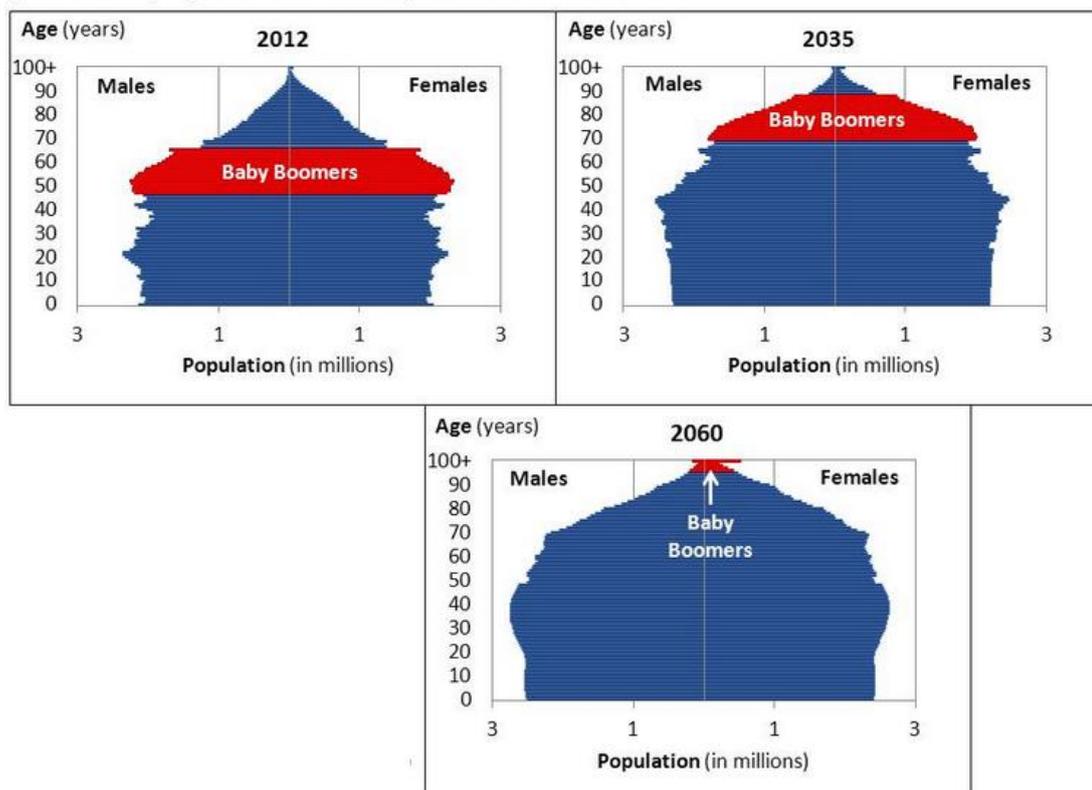
It is clear then that a new walking aid must be developed. This new design must help alleviate all of the issues of traditional walking aids. It must provide a safe and secure balance and stability, a method for ensuring proper posture, and a method for ensuring uninterrupted gait. The new design must also be aesthetically pleasing, so as to eliminate any uneasiness that the elderly may have regarding the stigmas surrounding walking aides.

## II.2 Description and Estimation of Market Size

Over 6.8 million Americans use devices to assist them with their mobility, 6.1 million of whom use walkers, canes, or crutches (Kaye, 3). Of the 1.8 million Americans who use walkers, “77 percent are 65 or older” (Mann, 1)(Kaye, 44). Therefore, we will target the roughly 1.4 million walker users that are aged 65 or older.

A study conducted in June 2000 found that 4.55 percent of all people over the age of 65 use walkers (Kaye, 47). In 2012, there were 43.1 million Americans over the age of 65, and this number is set to more than double to 92 million Americans by 2060 (Bernstein, 1). This population swell means that in 2060, 4.186 million elderly Americans will need walkers. The “oldest old” segment, those Americans aged 85 and older, will “more than triple from 5.9 million to 18.2 million” between 2012 and 2060. Since 16.53 percent of individuals over the age of 85 use walkers, there will be nearly 3.01 million Americans over the age of 85 using a walker (Kaye, 50). The increase in population of elderly Americans is due to the aging of the “baby boomer” population. The aging of baby boomers will create a dynamic and rapid growth of our target market over the next five decades.

### Population by Age and Sex: 2012, 2035 and 2060



**Figure II.2.1:** As the baby boomer generation ages, the proportion of the American population aged 65 and older will dramatically increase. This increase is projected to be sustained by an overall growth in population.

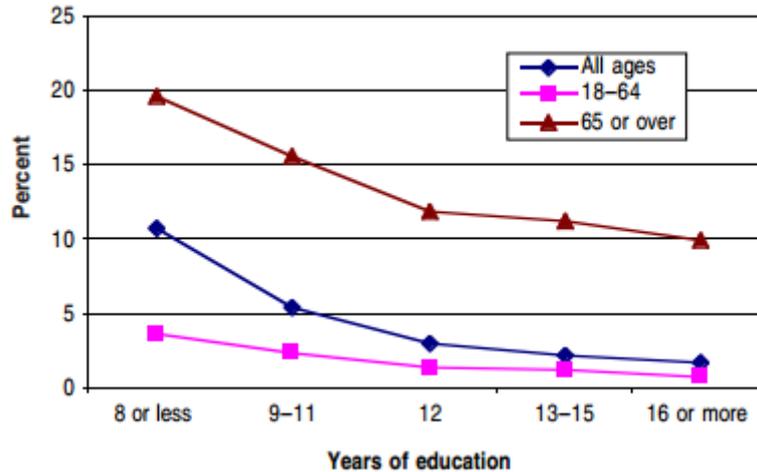
The populations of Maryland, Virginia, and Washington, D.C. account for roughly 4.66 percent of the total United States population (“States,” 1). In 2012, 65,240

Americans over the age of 65 who use walkers resided in Maryland, Virginia, or Washington, D.C.. In 2060, that number will jump to 195,068 Americans over the age of 65 who need walkers and reside in this region. As a start-up company based in the Washington Metropolitan Area, the design team would begin selling to those individuals who are over 65 years of age, use a walker, and reside in the Maryland, Virginia, Washington D.C. region. As the company grows, it would expand its target market to other large metropolitan areas across the United States in an effort to address the needs of a larger portion of Americans over the age of 65.

The demographics of Americans over the age of 65 also provide key insights into how our start-up firm addresses its target market. Table II.2.1 in the Appendix shows that 2.75 percent of men over the age of 65 use walkers, while 5.83 percent of women over the age of 65 use walkers (Kaye, 47). These proportions equate to 1.062 million females over the age of 65 who use walkers in America, as compared to the only 358,463 males over the age of 65 who use walkers (Kaye, 47) (Table II.2.1 in Appendix). This discrepancy is an important factor as our start-up firm considers marketing. Females and males respond to advertisements differently and perceive aesthetics differently. As we design a new walker, we must keep in mind that nearly 75 percent of our target market are women. Therefore, our walker should appeal strongly to women in order to harvest the largest amount of revenue possible.

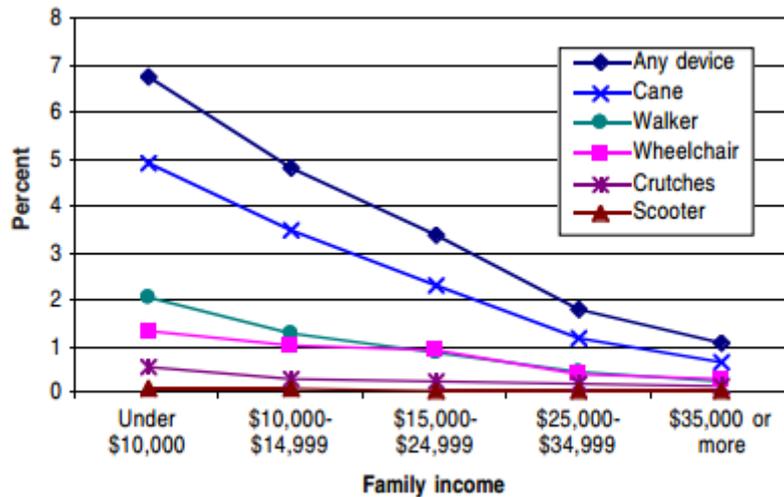
Mobility aid use also varies by ethnicity. Walker use, by proportion of racial population, is highest among Native Americans, followed by African Americans, Caucasians, and Asian/Pacific Islanders (Kaye, 47)(Table II.2.1 in Appendix). However, 1.26 million of the elderly who use walkers are Caucasian and 131,000 are African American (Kaye, 47)(Table II.2.1 in Appendix). When not normalized by total racial population size, it is clear that Caucasian and African American walker users combine to form 99.36 percent of our target market.

The proportion of the American population that uses walkers and other mobility devices increases as educational attainment decreases (Kaye, 10). Nearly 33.3 percent of Americans aged 65 and older who use walkers have 8 years or less of formal education. The proportion of walker users decreases to 27.5 percent for individuals with 12 years of education and 7.04 percent for individuals with 16 or more years of education (Kaye, 47)(Table II.2.1 in Appendix). This negative correlation suggests that a new walker design must be intuitive and easy to use, as large proportions of the target market will not have experience in higher education or a technical background.



**Figure II.2.2:** There is a negative correlation between years of education and percent of individuals who use walking aids.

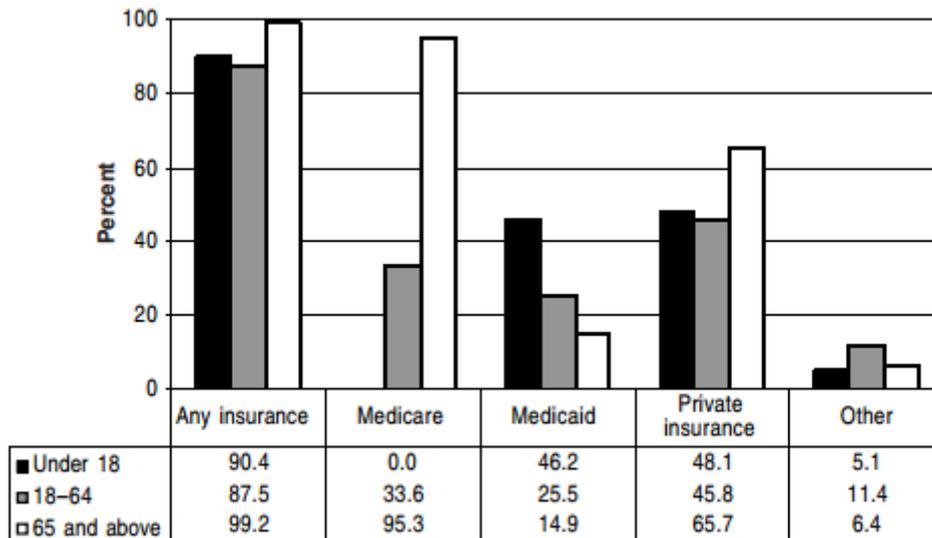
There is also a negative correlation between family income and percent of population using mobility devices (as education level and income are closely related). About 26 percent of Americans over the age of 65 who use walkers have a family income of under \$10,000 a year; 19.8 percent have an income between \$15,000-24,999 a year and 13.2 percent have an income of \$35,000 a year or more (Kaye, 47)(Table II.2.1 in Appendix). Approximately 16.2 percent of the target market also falls below the poverty line (Kaye, 47)(Table II.2.1 in Appendix). Since walker use increases as income decreases, the price point of our walker must be affordable for those individuals without insurance.



**Figure II.2.3:** Percent of individuals who use walkers increases as family income decreases.

Almost 100 percent of walkers, however, are covered by Medicare or some form of insurance. Among Americans aged 65 and older, 95.3 percent of walkers are paid for by Medicare and 65.7 percent of elderly walker users also have private insurance plans (Kaye, 35). As a start-up firm, most of our purchases will be paid for by Medicare or private insurance. This fact is important to recognize as dealing with insurance is different than selling directly to the customer. In many cases, insurance companies will only purchase products that are on their approved list. In order to sell

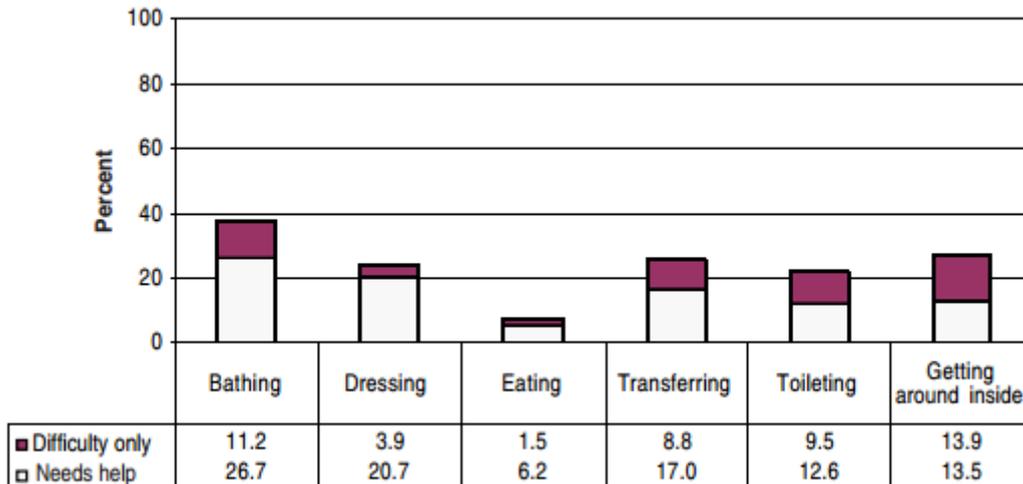
to the mass market, our new design will have to be approved by several of the major insurance companies and the Medicare program.



**Figure II.2.4:** Almost 100 percent of mobility devices used by Americans 65 and older are covered by some form of insurance.

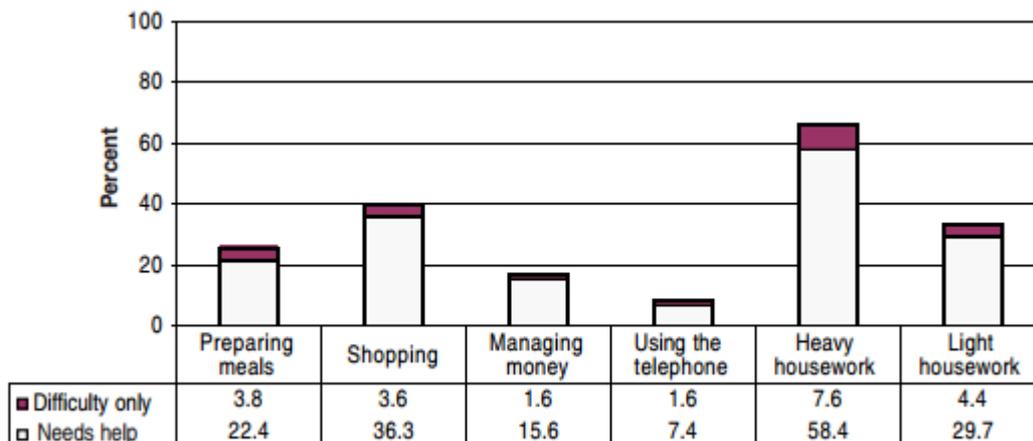
In addition to demographic information, it is important to recognize the ailments that walker users suffer from that dictates why they rely on walking frames. The most frequent conditions suffered by walker users over the age of 65 are osteoarthritis, cerebrovascular disease, orthopedic impairment of hip and/or pelvis, orthopedic impairment of lower extremities, and senility without mention of psychosis (Kaye, 56). A complete breakdown of conditions suffered by the elderly who use walkers can be found in Table II.2.2 in the Appendix. However, since a large portion of elderly users suffer from osteoarthritis and impairments of their hips, pelvis, or lower extremities, our new walker must support a large fraction of the user's weight since these lower body impairments will most likely mean that the users' legs cannot support their full body weight. Cerebrovascular diseases are also closely related to strokes. Users who have had strokes in the past might have limited feeling in certain portions of their body, including their hands and feet. Therefore, the design must ensure that the handles of the newly designed walker are easy to grasp and the walker base stays clear of the users' feet.

Many elderly users are also unable to complete activities of daily living (ADL), such as bathing, dressing, toileting, and eating, as well as instrumental activities of daily living (IADL), such as heavy housework, shopping, and preparing meals (Kaye, 20-22). Table II.2.3 in the Appendix shows the breakdown of ADL and IADL limitations for individuals over the age of 65 who use walkers. On a high level, 71.9 percent of walker users have any form of ADL limitation and 49.8 percent need assistance to perform ADL, self-care activities (Kay, 53). Almost 59 percent of elderly walker users have difficulty bathing, and 47.4 percent of elderly walker users have difficulty maneuvering inside their homes (Kay, 53). These two areas of difficulty suggest that the newly designed walker should be easy to maneuver throughout a user's home and should be maneuverable into the bathroom to assist in bathing.



**Figure II.2.5:** The graph above shows the proportion of mobility device users with ADL limitations by degree and type of limitation. While this graph shows data for all mobility devices from ages 5 and older, elderly who use walkers experience similar ADL issues.

Walker users over the age of 65 also have difficulty completing IADL home-management activities. Nearly 81 percent of walker users have difficulty completing heavy house-work and 65.2 percent of users have difficulty shopping. Adding storage capacity to the new walker design and ensuring that the new walker is easy to transport could help make shopping easier for elderly individuals. Similarly, ensuring that the walker can fit into tight spaces will help elderly individuals complete heavy housework with less difficulty.



**Figure II.2.6:** The graph above shows the proportion of mobility device users with IADL limitations by degree and type of limitation. While this graph shows data for all mobility devices from ages 18 and older, elderly who use walkers experience similar IADL issues.

### III. Problem Identification

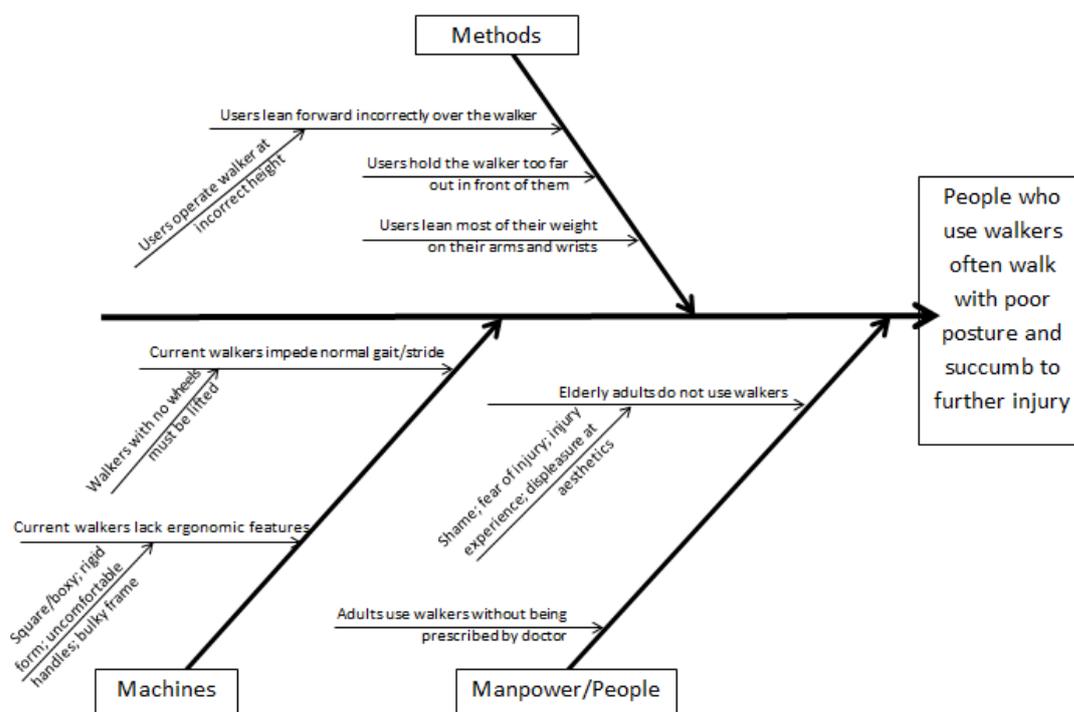
#### III.1 Problem Statement

Although there is a plethora of walk-assist devices available on the market today, many of these products actually hinder the users' mobility by limiting the users' gait

and by preventing correct ergonomic posture. As discussed in the Market Analysis section, walking aids can actually be detrimental to the user, especially to those users who are not adequately trained in the proper use of the device.

While most walkers aim to promote stability and provide improved maneuverability, users often develop bad habits, including leaning over the device in a bent-forward position and moving forward in a halting shuffle with an impeded gait. Such habits can lead to various muscular or skeletal injuries in the upper extremities, like shoulder and back irritation or ulnar nerve damage. These issues can lead to the elderly becoming increasingly dependent on the device, ultimately leaving the user with less mobility than when he or she began using the walker.

As these current walkers fail to actively promote correct posture and gait, the older adult users are at an increased risk of succumbing to fall-related injuries: over 47,000 fall injuries associated with walk-assist devices are recorded on an annual basis (Stephens, 1). In addition, many older adults who are in need of walking aids refuse to use them for fear of being ostracized by the general public. Mrs. Exelbert described the shame and fear felt by many of her peers of using walk-assist products in public, stemming from the embarrassment of needing such a device in the first place. As an ambulatory paraplegic herself, she stressed that using a traditional walker made her feel as if she was put on display. The device she described was an aesthetically-pleasing, alternative walk-assist device that she would feel comfortable using in public for ergonomic walking support. All of these contributing factors are visually summarized in the following Fishbone Diagram, which includes several of the “6 Ms” used in the manufacturing industry; namely, Machines, Manpower/People, and Methods (Tague).



**Figure 0.1** Cause-and-Effect/Fishbone Diagram

The problem is therefore very clear: the people who use current walk-assist devices often do so with poor posture and impeded gait, and may experience further injury. To address this challenge, the team plans to design a walk-assist device that will allow for a comparable level of stability, maneuverability, and safety as current competitive products, while actively encouraging and providing a means for correct ergonomics in posture and gait. This newly-designed product will also appeal to the user in an aesthetically pleasing way, in order to alleviate the stigma associated with using a walking aid.