

Portland State University  
Maseeh College of Engineering and Computer Science

# **Expandable Wheelchair**

---

## Product Design Specifications

Sponsor: Keen Mobility  
Industry Advisor: Rick Klein  
PSU Advisor: Faryar Etesami  
Team: Aleksey Synkov  
Joshua Hatch  
Meagan Pischel  
Robb Sparks

February 2, 2005

# Table of Contents

Introduction.....	1
Explanation of This Document.....	1
Mission Statement.....	2
Project Plan.....	2
Identification of Customers .....	2
Customer Feedback and Interviews .....	2
Product Design Specifications (PDS).....	3
High Priority .....	3
Medium Priority.....	7
Low Priority .....	8
Notes .....	8
House of Quality.....	9
Conclusions.....	10
Appendix I – Project Timeline.....	i
Appendix II – PDS Checksheet .....	iii

## Introduction

A manual wheelchair is a non-powered, low-cost, simple wheelchair. A typical model is shown in Figure 1. Skilled care facilities (a.k.a. nursing homes) and other institutions use large fleets of these chairs for patient transport and seating. For example, a patient will be transferred from his bed to a wheelchair, pushed or self-propelled to the dining hall, and take his meal while seated in the wheelchair.



**Figure 1- Manual Wheelchair; from [http://www.mobilitydeals.com/images/M2V\\_MERITS\\_STANDARD\\_MANUAL\\_WHEELCHAIR\\_NEW.jpg](http://www.mobilitydeals.com/images/M2V_MERITS_STANDARD_MANUAL_WHEELCHAIR_NEW.jpg)**

A limitation of current manual wheelchairs is the fixed dimensions of their seats, typically 18” wide by 16” deep. The growing girth of the American and other populations means these chairs are too small for a meaningful percentage of patients. For such patients, facilities must rent or purchase larger wheelchairs in addition to their existing fleets. This strains the limited budgets of the facilities and thereby decreases the standard of care for all patients. Accordingly, there is a need for a manual wheelchair with adjustable seat dimensions.

## Explanation of This Document

This set of Product Design Specifications (PDS) defines the requirements for the wheelchair design. It identifies external and internal customers for the product and, where possible, links quantifiable objectives to their needs.

## **Mission Statement**

Develop a low-cost manual wheelchair with adjustable seat width and depth for skilled care facilities. A prototype is to be completed by May 15, with design to be finalized by June 1.

## **Project Plan**

A Gantt chart detailing the project timeline is given in Appendix I. The major project milestones are the Product Design Specifications, Conceptual Design, Detailed Design, Prototype Testing and Production Release. The timeline is controlled by the requirements of ME 492/493.

## **Identification of Customers**

The primary customers for this product are skilled care facilities. Secondary external customers include patients and nursing staff who will use the chair.

Internal customers include marketing/sales, management/finance, legal, manufacturing, and shipping/warehousing.

## **Customer Feedback and Interviews**

Keen Mobility received an unsolicited request from a major customer for an adjustable wheelchair. Keen staff made themselves available for interviews on two occasions, answered e-mail questions, and attended a meeting of the design group. These interactions outlined and clarified the nature of the requested product.

The design team also visited a skilled care facility in Washington and interviewed a group of physical therapists. This visit highlighted a number of practical considerations and “front-line” requirements for the product.

Information from these interviews was used heavily in the development of this PDS.

## Product Design Specifications (PDS)

### *High Priority*

<b>Criterion</b>	Performance	
<b>Requirement</b>	Seat width	
<b>Primary Customer</b>	Patient	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Seat width adjustable by user	Inches	16 through 20 – 2 inch increments
<b>Target Basis</b>	Market research	
<b>Verification Method</b>	Prototyping	

<b>Criterion</b>	Performance	
<b>Requirement</b>	Seat depth	
<b>Primary Customer</b>	Patient	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Seat depth (front-back) adjustable by user	Inches	16 through 18 – 1 inch increments
<b>Target Basis</b>	Market research	
<b>Verification Method</b>	Prototyping	

<b>Criterion</b>	Performance	
<b>Requirement</b>	Able to support large patients	
<b>Primary Customer</b>	Patients	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Load Capacity	Pounds	300
<b>Target Basis</b>	Market research	
<b>Verification Method</b>	Stress analysis, prototyping	

<b>Criterion</b>	Performance	
<b>Requirement</b>	Able to fit through standard residential doorways	
<b>Primary Customer</b>	Patients	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Overall Width	Inches	28
<b>Target Basis</b>	Standard door width	
<b>Verification Method</b>	Solid modeling, prototyping	

<b>Criterion</b>	Environment	
<b>Requirement</b>	Withstand operation in a Skilled Nursing Facility	
<b>Primary Customer</b>	Nursing home, patients	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Withstands Corrosion	Years	15
Withstands Extreme Temperature	Degrees F	-40 to 150
<b>Target Basis</b>	Market Analysis	
<b>Verification Method</b>	Temperature and water testing	

<b>Criterion</b>	Life in Service	
<b>Requirement</b>	Appropriate service life for capital asset	
<b>Primary Customer</b>	Nursing home	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Life	Years	15 for frame 5 for seat
<b>Target Basis</b>	Market Analysis	
<b>Verification Method</b>	Endurance testing	

<b>Criterion</b>	Aesthetics	
<b>Requirement</b>	Upbeat, “non-medical” appearance	
<b>Primary Customer</b>	Marketing, Patients	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Appearance	Subjective	Bright colors; interesting lines; visually “softer” materials (e.g. seat/back)
<b>Target Basis</b>	Competing chairs; reference current Keen products	
<b>Verification Method</b>	Subjective comparison; consultation with Keen personnel	

<b>Criterion</b>	Legal (Patents, Product Liability)	
<b>Requirement</b>	Minimized product liability issues	
<b>Primary Customer</b>	Keen; facilities (chair owners)	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
	N/A	Free from design defects; minimized sensitivity to manufacturing defects
<b>Target Basis</b>	Published standards; good design practice	
<b>Verification Method</b>	Design review	

<b>Criterion</b>	Legal (Patents, Product Liability)	
<b>Requirement</b>	No patent infringement	
<b>Primary Customer</b>	Keen; facilities (chair owners)	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
	N/A	Unique design
<b>Target Basis</b>	Published patents & applications	
<b>Verification Method</b>	Patent search; design review	

<b>Criterion</b>	Maintenance	
<b>Requirement</b>	Easy to maintain	
<b>Primary Customer</b>	Nursing home staff	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
	Simple tools to perform maintenance	Perform maintenance when pressure washing occurs (irregularly)
<b>Target Basis</b>	Competing chairs	
<b>Verification Method</b>	Prototyping; design review	

<b>Criterion</b>	Installation	
<b>Requirement</b>	Quick, tool-free size adjustment	
<b>Primary Customer</b>	Nursing home staff	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Time	Minutes	5
<b>Target Basis</b>	Nursing home staff interviews	
<b>Verification Method</b>	Prototyping	

<b>Criterion</b>	Installation	
<b>Requirement</b>	Chair only adjustable by staff, not patients	
<b>Primary Customer</b>	Nursing home staff	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Number of people needed to adjust chair	N/A	N/A
<b>Target Basis</b>	Nursing home staff interviews	
<b>Verification Method</b>	Prototyping	

<b>Criterion</b>	Ergonomics	
<b>Requirement</b>	Patients should find chair comfortable for long periods	
<b>Primary Customer</b>	Patients	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Time	Hours	12-14
<b>Target Basis</b>	Nursing home survey	
<b>Verification Method</b>	Prototyping	

<b>Criterion</b>	Ergonomics	
<b>Requirement</b>	Staff should not hurt their shins maneuvering chair	
<b>Primary Customer</b>	Nursing home staff	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Chair components	Clearance	Inches or degrees
<b>Target Basis</b>	Staff interviews	
<b>Verification Method</b>	Solid modeling	

<b>Criterion</b>	Safety	
<b>Requirement</b>	Conformity with ANSI/RESNA Wheelchair Standards	
<b>Primary Customer</b>	Patients, nursing home staff	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Various per standards	Per standards	Per standards
<b>Target Basis</b>	Legal	
<b>Verification Method</b>	Solid modeling; prototype testing	

<b>Criterion</b>	Quality & Reliability	
<b>Requirement</b>	Usage (daily, abusive)	
<b>Primary Customer</b>	Primary user, nursing facility	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Design for daily (not intermittent) use	% overload designed for	100%
<b>Target Basis</b>	Keen expert information; facility staff interviews	
<b>Verification Method</b>	Prototyping; standards; various analyses	



## Medium Priority

<b>Criterion</b>	Documentation	
<b>Requirement</b>	User's documentation information to Keen	
<b>Primary Customer</b>	Primary user, nursing facility	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Step-by-step adjustment instructions	N/A	N/A
<b>Target Basis</b>	Keen expert information	
<b>Verification Method</b>	Market research, standards	

<b>Criterion</b>	Shipping	
<b>Requirement</b>	Maximize utilization of standard shipping container	
	Single chair should be UPS non-oversized	
<b>Primary Customer</b>	Manufacturing, Warehousing	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Packed dimensions	Cubic Meters	TBD
<b>Target Basis</b>	ISO container standards; UPS guidelines	
<b>Verification Method</b>	Solid modeling; prototyping	

<b>Criterion</b>	Size and Shape	
<b>Requirement</b>	Chair will be collapsible in width	
<b>Primary Customer</b>	Patients	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Width	Inches	10
<b>Target Basis</b>	Market Analysis	
<b>Verification Method</b>	Solid modeling; prototyping	

<b>Criterion</b>	Materials	
<b>Requirement</b>	All parts should be latex free	
<b>Primary Customer</b>	Patients	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Product materials	Latex content	Zero
<b>Target Basis</b>	Market analysis	
<b>Verification Method</b>	Part vendor specifications	

## Low Priority

<b>Criterion</b>	Disposal	
<b>Requirement</b>	Minimal wear/replacement	
	Recyclable	
<b>Primary Customer</b>	Facilities (chair owners); marketing	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Chair & component life expectancies; materials, assembly methods used	Years; qualitative	Low part replacement requirements; easy disassembly for recycling
<b>Target Basis</b>	Competing chairs	
<b>Verification Method</b>	Analysis of wear components	

<b>Criterion</b>	Weight	
<b>Requirement</b>	Minimum weight for ease of use and low shipping costs	
<b>Primary Customer</b>	Shipping, Patients, Nurses	
<b>Metrics &amp; Targets</b>	<b>Metric</b>	<b>Target</b>
Total chair weight	Pounds	≤45
<b>Target Basis</b>	Competition + allowance for adjustment mechanism	
<b>Verification Method</b>	Solid modeling; prototyping	

## Notes

- Keen requires prior approval for researching and prototyping expenditures.
- Final drawings must be done in SolidWorks (Keen's software of choice).
- Keen has indicated extreme durability problems with aluminum manual wheelchairs currently on the market.
- For safety reasons, the occupant of the chair should not be able to adjust the chair while seated in it.
- Users insist upon puncture-proof, maintenance-free tires.
- Current chairs have problems with seat material stretch over time.
- The wheelchair must preserve the independent front/rear height adjustment, foldability, and folding or removable arm rests found on current chairs.
- Sales volume will be 100/month for the first year, with increase in subsequent years.
- The wheelchair will be produced in the Far East with a target cost of ≤US\$100/unit.

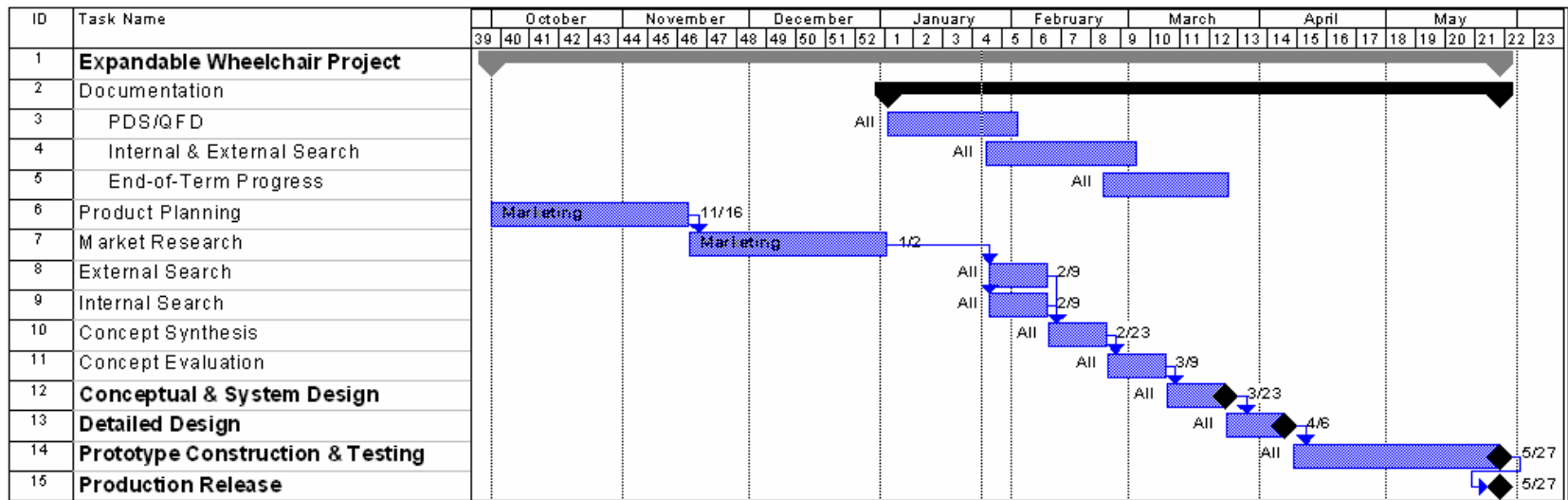
# House of Quality

<i>Expandable Wheelchair House of Quality</i>															
Customer needs	Importance	End User	Performance and Parameters										Market Competition		
			Seat Width	Seat Depth	Chair Weight	Daily Use	Weight Capacity	Foldability	Install Time	Latex Free	Life in Service	Price	Breezy 510	Guardian Escort	Invacare IVC Tracer EX2
<b>Performance</b>															
Adjustability	<input checked="" type="checkbox"/>	Patient	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>							<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Safety	<input checked="" type="checkbox"/>	Nursing Facility	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>				<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Materials	<input type="checkbox"/>	Patient				<input checked="" type="checkbox"/>				<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>				
Ergonomics	<input checked="" type="checkbox"/>	Patient, Facility	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>					<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>
Maintenance	<input checked="" type="checkbox"/>	Nursing Facility	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Quality and Reliability	<input checked="" type="checkbox"/>	Patient, Facility	<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>	<input checked="" type="checkbox"/>		<input checked="" type="checkbox"/>		<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Price	<input checked="" type="checkbox"/>	Nursing Facility											<input type="checkbox"/>	<input checked="" type="checkbox"/>	<input type="checkbox"/>
<b>Market Competition</b>															
Breezy 510			14", 16", 18", 20"	16", 18"	30 lbs	12 to 14 hr	250		no		Frame lifetime	\$427			
Guardian Escort			16", 18", 20"	16"	37 lbs	12 to 14 hr	250	14"	no		Frame lifetime	\$271			
Invacare IVC Tracer EX2			16", 18", 20"	16"	36 lbs	12 to 14 hr	250		no		Frame lifetime	\$350			
<b>Target</b>			16" to 20"	16" to 18"	45 lbs or less	12 to 14 hr	300	10"	5 min	yes	Frame 15 yr, components 5 yr	\$250			

## **Conclusions**

While the product's unique requirements are simple – adjustable seat width and depth – it must also meet a broad range of requirements common to all wheelchairs. These include durability, cleanability, foldability, and compliance with published standards. In particular, designing a robust expansion mechanism while remaining cost and weight competitive will present strong design challenges.

## **Appendix I – Project Timeline**



Project: Expandable Wheelchair Date: Tue 1/25/05	Task		Rolled Up Task		Project Summary	
	Split		Rolled Up Split		External Milestone	
	Progress		Rolled Up Milestone		External Milestone	
	Milestone		Rolled Up Progress		Deadline	
	Summary		External Tasks			

## Appendix II – PDS Checksheet

Criteria	Pages
Performance	3
Environment	4
Life in service	4
Quantity	Notes (8)
Cost of production per part (material and labor)	Notes (8)
Size and Shape	7
Weight	8
Maintenance	5
Installation	5
Ergonomics	5-6
Safety	6
Materials	7
Manufacturing facilities	Notes (8)
Shipping	7
Packaging	7 (see Shipping)
Aesthetics	4
Quality and Reliability	6
Applicable codes and standards	6 (see Safety)
Testing	See “Verification Method” by item
Company constraints and procedures	Notes (8)
Documentation	7
Legal (Related patents)	4-5
Competition products	HOQ (9)
Timelines	Appendix I (ii)
Disposal	8