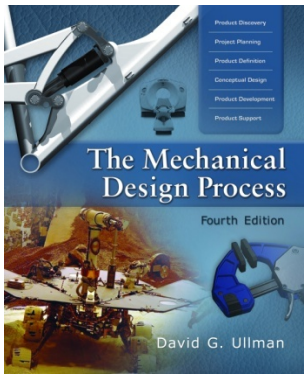
Reinventing the See-Saw at BigToys



A Case Study for The Mechanical Design Process

Introduction

Until late in the 20th century a see-saw or teeter-totter was found in nearly every public park and school playground in America. The concept of a see-saw probably goes back before recorded history – to the first time some cave-kid put a stiff branch across a log and had his friend sit on the other end. But, with the concern for safety and with increased litigation, see-saws had all but disappeared by the beginning of the 21st century. Responding to a play void, BigToys Inc., a manufacturer of playground equipment reinvented the see-saw in 2005 as a product they call The Rock'n Cross™[i].

Where the see-saw evolved over time, The Rock'n Cross was purposely designed in tight cooperation with customers, right down to the product's name. How BigToys went about this classic-toy redesign will be explored in light of Quality Function Deployment (QFD) and other customer-centric best practices. Thus, this case study focuses on the design of a 21st century see-saw. Specifically:

Figure 1. Big Toys Rock 'n Cross

The Problem: Design a new see-saw that can meet 21st Century safety concerns.

The Method: The Rock'n Cross was designed in close cooperation with children, those concerned with their safety and other customers. The conceptual design process loosely followed the steps found in Quality Function Deployment (QFD) and the product was developed on Autodesk® Inventor®.

Advantages/disadvantages: Focusing on customers and interacting with them takes time but results in a better product. The Rock 'n Cross has been well received by Big Toy's customers.

Background

The see-saw has been around a long time. There are Greek vase paintings of children playing on seesaws and the toy surely dates back long before then. One early depiction of it in art is in Jean-Honore Fragonard's 1755 painting, "The See-Saw" (Figure 2). In this romantic image, the cooperative play feature that has made the toy a favorite throughout history is clear with three people actively enjoying the experience. This "cooperative play" feature is important to the Rock 'n Cross as can be seen with the five children playing on it in Figure 1.

Figure 2. The See Saw, 1755

Modern playgrounds began in the US around the turn of the century. These playgrounds were conceived as a respite for urban children and a place for exercise. The 1960s saw another boom in playground development, spurred by John F. Kennedy's Council on Youth Fitness. Again, the dominant purpose was exercise. These playgrounds were mostly the same: paved ground, chain-link fences, and steel swings, slides, see-saws and merry-go-rounds.

In spite of the long history and cooperative play advantages, the see-saw began to disappear from public playgrounds and schools in the United States in the 1990s. This was due to safety hazards, or at least perceived safety hazards. Historically, see-saw related injuries are caused by:

- Falling from the raised side or while standing on top of it
- Smashing into the ground by the person on the high side when the lower person jumps off
- Pinching injuries from fingers in the pivot mechanism
- Hitting injuries with a person standing on the ground being struck by the see-saw either with people on it or with it pushed in motion while empty

While the injury potential may seem great, some statistics can put them into perspective. Each year more than 215,000 American children go to emergency rooms due to playground injuries. But of these, only about 3%[ii] of the injuries are attributable to see-saws, with a majority of these due to falls on hard surfaces. This 3% compares to monkey bars (29%), slides (27%), swings (25%), and play structures (16%). Across all these injuries, falls account for 67% of them while being hit by or hitting against equipment is another 12%. Of the see-saw injuries, only 6.5% resulted in hospitalization compared to 14% for monkey bars and 7.5% for swings. So, even though see-saws are perceived as dangerous, relative to other playground hazards they are not a major cause of injury. With proper surfaces under them, see-saws are not very dangerous with the perception greater than the reality.

With this background, this case study focuses on how BigToys used their customers to help them redefine the see-saw. It primarily focuses on participatory design with children, even down to a contest for children to name the product.

Hearing the voice of the Customer

An important first step in any design is to learn what the customer wants, not just what engineers think they want. An oft used method to accomplish this is to use the Quality Function Deployment (QFD) method. BigToys did not formally use QFD, however they executed many of the steps in the process and so the QFD serves as a good framework for describing Big Toy's early design work on the Rock n' Cross, the see-saw for the 21st century.

The QFD method was developed in Japan in the mid-1970s and introduced in the United States in the late 1980s. Using this method, Toyota was able to reduce the costs of bringing a new car model to market by over 60 percent and to decrease the time required for its development by one-third. It achieved these results while improving the quality of the product. A recent survey of 150 U.S. companies shows that 69 percent use the QFD method and that 71 percent of these have begun using the method since 1990. A majority of companies use the method with cross-functional teams of ten or fewer members. Of the companies surveyed, 83 percent felt that the method had increased customer satisfaction and 76 percent indicated that it facilitated rational decisions.

Applying the QFD steps builds the *house of quality* shown in Fig. 3. This house-shaped diagram is built of many rooms as shown in the left half of the diagram. On the right is a house that was completed for the design of "aisle chair", a wheel chair that fits in airliner aisles. This study was completed for Boeing as part of their Dreamliner development and is described in more detail in *The Mechanical Design Process*. As can be appreciated, the QFD can get complex, but here the rooms in the house are only used to describe Big Toy's effort.

Developing information in the house of quality begins with identifying *who* (step 1) the customers are and *what* (step 2) it is they want the product to do. In developing this information, we also determine to whom the "what" is important—*who versus what* (step 3). Then it is important to identify how the problem is solved *now* (step 4), in other words, what

the competition is for the product being designed. This information is compared to what the customers desire—*now versus what* (step 4 continued)—to find out where there are opportunities for an improved product. Next comes one of the more difficult steps in developing the house, determining *how* (step 5) you are going to measure the product's ability to satisfy the customers' requirements. The hows consists of the engineering specifications, and their correlation to the customers' requirements is given by *whats versus hows* (step 6). Target information—*how much* (step 7)—is developed in the basement of the house. Finally, the interrelationship between the engineering specifications are noted in the attic of the house—*how versus how* (step 8).

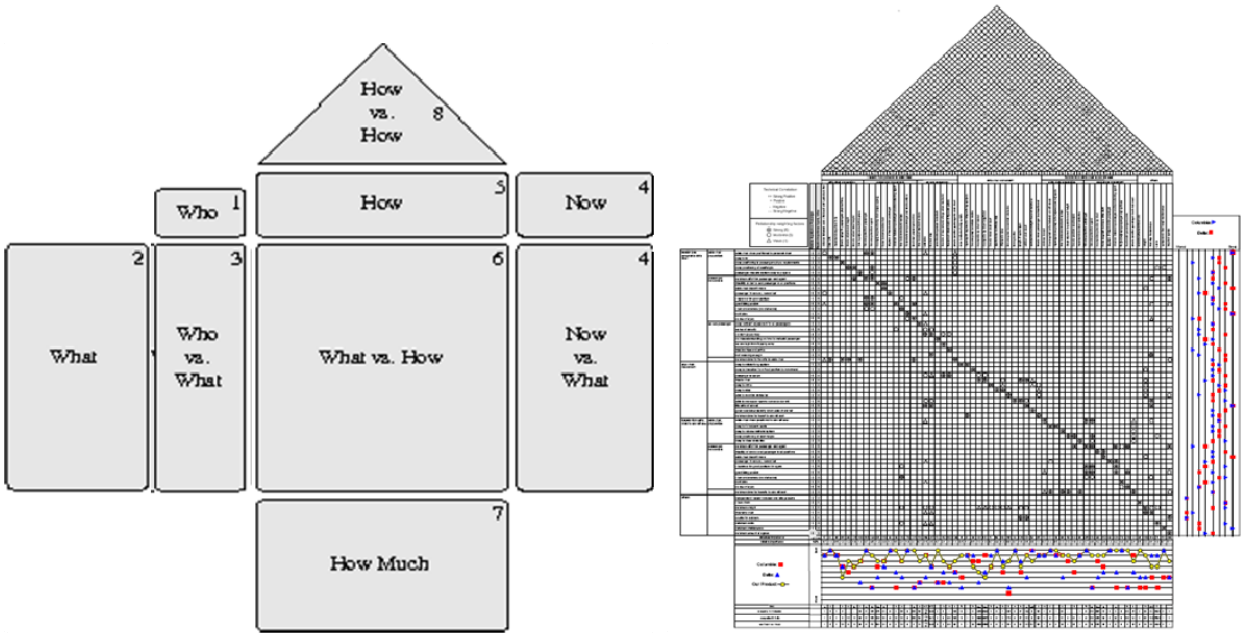


Figure 3. Quality Function Deployment

STEP 1: IDENTIFY THE CUSTOMERS: WHO ARE THEY?

For most design situations there is more than one customer. In *The Mechanical Design Process*, a customer is defined as any person who comes in contact with the product, its manufacture, sales, and use. The customers are the "who" in the QFD diagram (room #1). The most obvious customers for see-saws are children. But not all children play the same. The Consumer Product Safety Commission (CPSC) categorizes play ground equipment by age groups: toddlers, <2 years old; Preschool-age, 2-5 years old; School-age, 5 -12 years old; and > 12 years old. The Rock n' Cross was designed for school-aged children, but 5 year old children play differently than 12 year olds do, a difference described in the section below on Prototype Testing. Thus, the first two customers are:

- 5 year old children
- 12 year old children

The second most important customer is the playground supervisor. These are the adults who are responsible for safety and for equipment logistics (e.g. what to do if there is more demand than there is equipment). It is estimated that more than 40 percent of playground injuries are related to inadequate supervision. Since many playgrounds in the US are at schools and the supervision at schools is provided by teachers, this estimate highlights another influence on the demise of the see-saw. Namely, those responsible for playground supervision want equipment that is easy to supervise and safe to use. It is clear that the demise of see-saws is as much about supervision as it is about safety[iii]. Thus, the third customer is:

- Playground supervisors

But, they are not the ones who actually specify the equipment. This is usually done by a landscape architect, school principal or park official. Thus, another customer is:

- Playground equipment specifiers

To support the development of safe playground equipment the federal Consumer Product Safety Commission (CPSC) was created in 1972. Based on its study of playground injuries it produced Handbook 325[iv], "Public Playground Safety Handbook". This handbook, last updated in 2008, details the safety requirements for seesaws and other equipment. Also, there are at least 5 ASTM standards for playground equipment (ASTM STD F1487[v]) and surfaces, leading to another see-saw customer:

- Safety Standards and their organizations

Finally the people who install and maintain the equipment are also customers, adding one more customer to the list:

- Installation/Maintenance personnel

In developing the Rock n' Cross, BigToys kept all of these customer groups in focus through working to understand what each of them wanted in the product.

STEP 2: DETERMINE THE CUSTOMERS' REQUIREMENTS: *WHAT* DO THE CUSTOMERS WANT?

The second step in QFD (room #2) is to determine what each of the customer groups wants in a see-saw. A partial list of requirements is given in Table 1. The first three customer requirements are in the voice of the children. But, supervisors also voice the need for fun and cooperative play as equipment that provides these capabilities are easier to manage. The last customer requirement is needed as some playground equipment is installed where holes can't be bored into the ground such as indoors.

Requirement	Customer(s)
Fun to Play on	Children and supervisors
Can play with my friends	Children and supervisors
Can play alone if I am the only one there	Children
Needs minimal supervision	Supervisors
Safe to use	Supervisors, Specifiers and Safety Standards
Reliable	Supervisors and maintenance
Meet ASTM Std F1487, CPSC 325	Specifiers
Inexpensive to purchase, install and maintain	Specifiers, installation and maintenance
Can be surface mounted	Installers

Table 1: Room 2 of the QFD, the Customers' Requirements

STEP 3: DETERMINE RELATIVE IMPORTANCE OF THE REQUIREMENTS: *WHO VERSUS WHAT*

The next step in the QFD technique is to evaluate the importance of each of the customers' requirements (Room #3). BigToys did not do this in any formal way, but treated all the requirements as important.

STEP 4: IDENTIFY AND EVALUATE THE COMPETITION: HOW SATISFIED ARE THE CUSTOMERS NOW?

The goal in room #4 of the QFD is to determine how the customer perceives the competition's ability to meet each of the requirements. The purpose for studying existing products is twofold: first, it creates an awareness of what already exists (the "now"), and second, it reveals opportunities to improve on what already exists. In some companies this process is called *competition benchmarking* and is a major aspect of understanding a design problem. In benchmarking, each competing product must be compared with customers' requirements (now versus what). Here we are only concerned with a subjective comparison that is based on customer opinion.

BigToys primary competition was the traditional see-saw. Although BigToys did not complete a comparison as formal as this, their opportunities become obvious using the QFD format. In Table 2, the scoring is on a scale of 1 to 5:

The product does not meet the requirement at all.
The product meets the requirement slightly.
The product meets the requirement somewhat.
The product meets the requirement mostly.
The product fulfills the requirement completely.

Requirement	Traditional see-saw				
	1	2	3	4	5
Fun to Play on					●
Can play with my friends			●		
Can play alone if I am the only one there			●		
Needs minimal supervision		●			
Safe to use		●			
Reliable					●
Meet ASTM Std F1487, CPSC 325			●		
Inexpensive to purchase, install and maintain					●
Can be surface mounted					●

Table 2: Room 4 of the QFD, The competition

As can be seen, the new product should be one that does not hurt the play quality or reliability for the traditional see-saws (score =5). The market opportunity (scores of 3 or less) is for a product that can entertain more children in a safe manner, can even be used alone, if desired and is safe to use.

The goal of the next four steps in the QFD is to determine how to measure the customers' requirements. These will be discussed together.

STEP 5: GENERATE ENGINEERING SPECIFICATIONS: *HOW* WILL THE CUSTOMERS' REQUIREMENTS BE MET?

STEP 6: RELATE CUSTOMERS' REQUIREMENTS TO ENGINEERING SPECIFICATIONS: *HOW* TO MEASURE *WHAT?*

Step 7: SET ENGINEERING SPECIFICATION TARGETS AND IMPORTANCE: *HOW MUCH* IS GOOD ENOUGH?

STEP 8: IDENTIFY RELATIONSHIPS BETWEEN ENGINEERING SPECIFICATIONS: HOW ARE THE *HOWS* DEPENDENT ON EACH OTHER?

Many small companies who produce low technology products do not feel that they have the resources to follow these QFD steps. Also, companies that design products with high human interface often feel that requirements like "fun to play on" can not be reduced to measurable engineering specifications. However, projects like the aisle chair shown in Figure 3 give strong indication that working through these steps is worthwhile. None-the-less, BigToys did not do these QFD steps. Instead they developed concepts and built prototypes of their favorite design using these to determine, in an informal way, how well the customers' requirements were met.

Concept Development

BigToys did not start out to design a new see-saw. They contracted with an industrial designer who specialized in playground equipment and had worked closely with BigToys for many years to develop ideas for cooperative play products. He saw the demise of the traditional see-saw as an opportunity and included sketches of what was to become the Rock n' Cross in a group of ideas presented to BigToys'. Two of his sketches are shown in figure 4

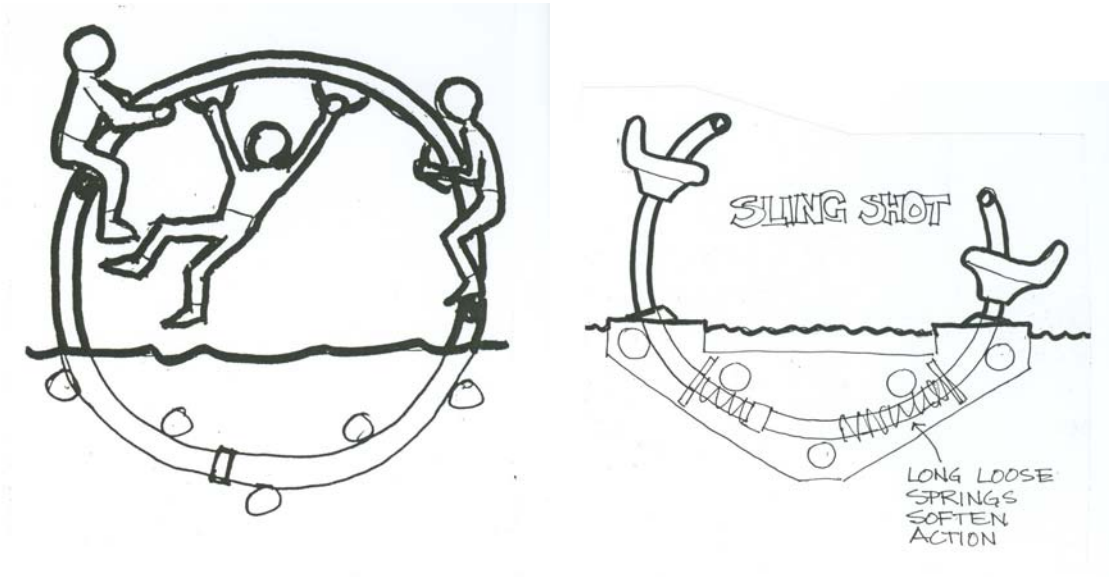


Figure 4 Sketches for what was to become the Rock n' Cross

The sketches show the original germ of the concept. In each, the tilting of the traditional see-saw has been replaced by a mechanism that moves the riders in the same circular path as is traditional, but using a rotating arc rather than a pivot. Where see-saws balance due to weight distribution, these concepts are centered using springs as shown in the right-hand, "Sling Shot" diagram. In the diagram on the left, the concept that was to become the Rock n' Cross, the springs are not shown, but are implied. Also, shown on the left-hand diagram is the cooperative play that was to become an important feature of the Rock n' Cross.

Figure 5. Spring-centered see-saw

The idea of using springs to center see-saws is not new as there are units on the market such as the example in Figure 5. Here the springs not only center the riders rotationally, they support them and provide lateral stiffness. This style of see-saw is unconstrained in its motion about all axes and in all directions. Its performance is very dependent of the weight of the riders. The Rock n' Cross on the other hand is constrained to one degree of freedom, like a traditional see-saw.

In Table 3, the Rock n' Cross concept, the left-hand diagram in Figure 4, is compared to the traditional see-saw using the customers' requirements by updating Table 2. The concept fulfils most of the requirements, at least on paper. It is only given a score of 3 on the first 2 requirements because these are hard to evaluate on paper. They could have been better accessed without building prototypes, if the final steps of the QFD had been completed. Also, the reliability is unknown from the sketches. Finally, neither of the concepts can be surface mounted and so they are given low scores.

Requirement	● Traditional see-saw ■ Rock n' Cross concept ▲ Final Rock n' Cross				
	1	2	3	4	5
Fun to Play on			■?		▲●
Can play with my friends			● ■?		▲
Can play alone if I am the only one there			●		■▲
Needs minimal supervision		●			■▲
Safe to use		●			■▲
Reliable			■?		▲●
Meet ASTM Std F1487, CPSC 325			●		■▲
Inexpensive to purchase, install and maintain		▲■			●
Can be surface mounted	■				▲●

Table 3. Now room of QFD updated with concept and final Rock n' Cross

Based on the market potential and increased safety over the competition and the other feature made evident in Table 3, the internal steering committee selected the Rock n' Cross concept as one idea to develop to the prototype stage. Focus during detail design was to make all the requirements score 5, with the exception of cost. Where traditional see-saws are very inexpensive, for the Rock n' Cross, cost was clearly going to be higher due to relative complexity. Purchase cost was not seen as critical and subsequent sales have proved this assumption correct.

Prototype Testing

Based on the concepts, detailed design was begun and a prototype was built out of plastic materials. During the detailed design, sufficient new functionality was developed that a patent was applied for and granted. The patent featured nine claims. Paraphrasing the first claim, there is an arc shaped playground device that has two parts. The first part is a fixed rail and the second a moving member with seats on the ends. The moving portion is spring loaded to a predetermined position allowing it to move to-and-fro on the rail. This can be seen in Figure 6, an assembly drawing showing (on the top) the "fixed rail", a pipe, with the springs added in the middle drawing and then finally with the "moving member" shown on the bottom.

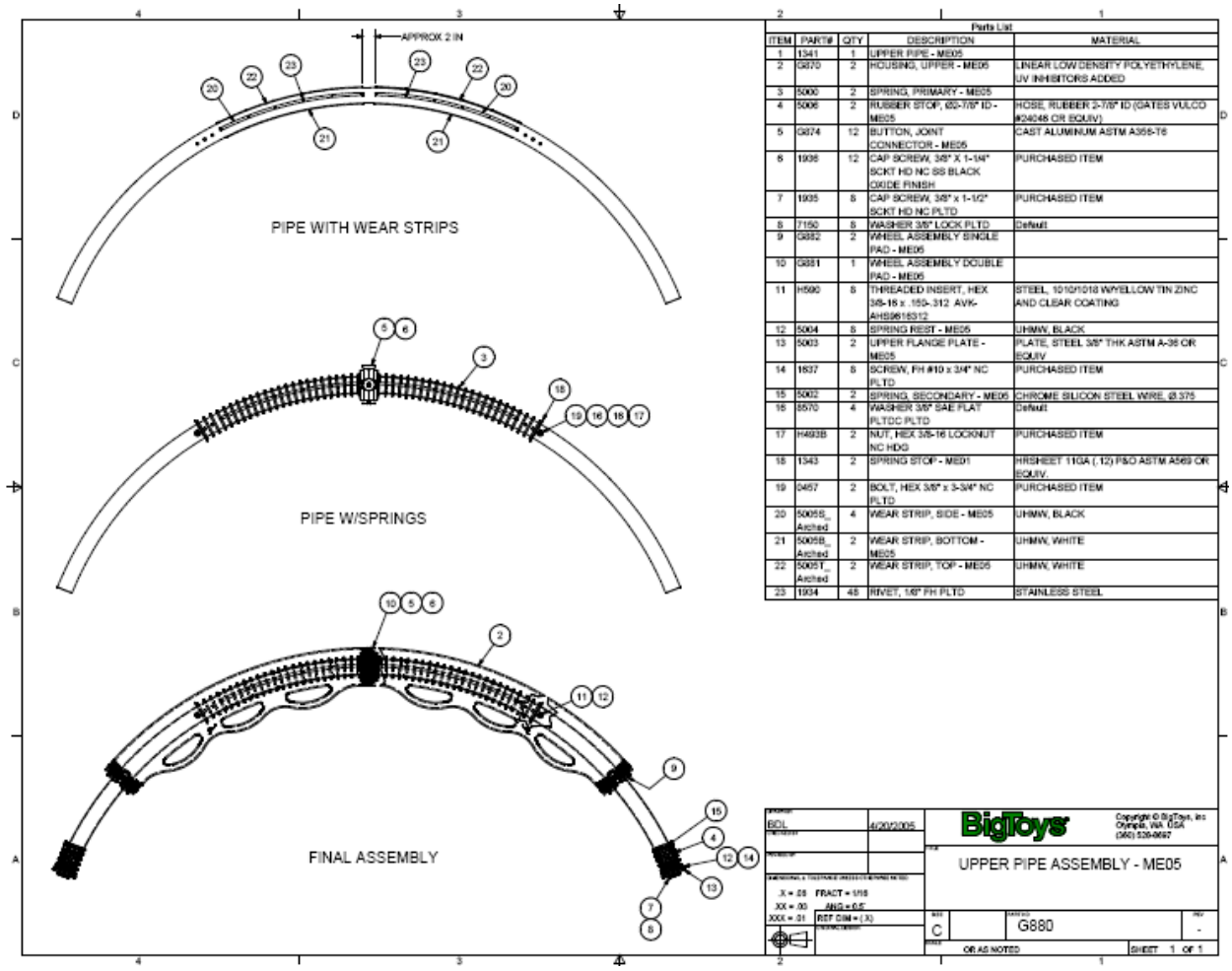


Figure 6. Pipe Structure of the Rock n' Cross

Moving all the springs and guides internal to the part above the ground as shown in Figure 6, resolved the poor "surface mounted" score in Table 3.

The prototype was designed to test the function of the product. As pointed out in *The Mechanical Design Process*[vi] and in the case study "*Spiral Product Development at Syncromatics*" [vii] there are three reasons to develop prototypes, to test the function of the product, to test the design of the product itself (i.e. fit assemblability, etc), or to test the processes for manufacturing the product. This first prototype was sufficient for testing the function with children in an internal environment.

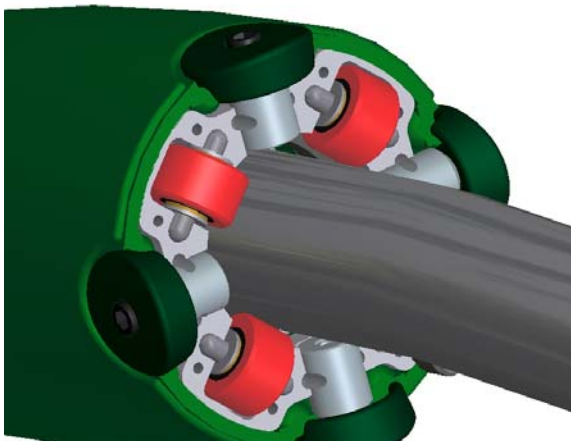


Figure 6. Rock n' Cross truck

One detail developed and tested during this period was the truck, Figure 7. The truck serves two purposes. It locks together sections of the moving tubing and supports the wheels that run on the fixed pipe. In the figure, the red wheels

roll on the inner steel pipe and the green, round fasteners attach a section of outer pipe to the truck. An adjacent section of pipe is attached to the truck in a similar manner, but is not shown here.

After design refinements were made based on tests on the first prototype, a refined product prototype was developed and installed on a playground at a local school. At first the children played on it, but after 1 month no one was using it. BigToys interviewed and observed the children to learn why the loss of enthusiasm for the product. They learned that:

- Five year olds play differently than twelve year olds. The younger children are more cooperative. As shown in Figure 1, some children act as helpers to the children who are sitting on the Rock n' Cross. The idea of a helper may have been hard to see during the QFD development, but on-the-other-hand, the painting in Figure 2 clearly shows a helper, another "customer" for this toy, so maybe the concept of cooperative play could have been developed earlier. Twelve year olds are more competitive and like the challenge and risk of hanging on the middle while other try to shake them off. In fact this has become such a feature of the Rock n' Cross that the logo for the toy has a stick man hanging on and being shaken. Compare this logo to the child hanging on the middle of Figure 1. This change in play challenge has been a unique factor for the Rock n' Cross.

- Playground supervisors thought that supervision was much lower than that needed for the traditional see-saw.

Subsequent to these tests, some changes were made and the product finalized. During this period a naming contest was held as part of a PR campaign and a 1st grader from Maine submitted the name Rock n' Cross. She won a Rock n' Cross for her school.

Conclusions

BigToys has developed a 21st century see-saw that meets all the customer's requirements with the exception that it is more expensive than a traditional see-saw. However, with the increase in play value, safety and ease of supervision, this has had little effect on sales. The toy is a favorite of children and play ground supervisors. It has proven to be challenging, foster cooperative play and proven safe to play on.

While BigToys did not use the QFD process, they achieved many of the QFD results. Using the QFD may have saved them some development effort.

Author

This case study was written by David G. Ullman, Emeritus Professor of Mechanical Design from Oregon State University and author of The Mechanical Engineering Process, 4th edition, McGraw Hill. He has been a designer of transportation and medical systems and hold five patents. More details on David can be found at www.davidullman.com. David was assisted by Brian Lovgren and Tim Madeley of BigToys Inc of Olympia Washington.

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[i] Rock n' Cross details

[ii] Based on 1996 Canadian statistics from the CHIRPP News, Canadian Hospitals Injury Reporting and Prevention Program, Issue 12, Nov 1997.

[iii] Communication with Donna Thompson, National Public Playground Safety Institute

[iv] CPSC Public Playground Safety Handbook,

[v] F1487 Standard Consumer Safety Performance Specification for Playground Equipment for Public Use

[vi] See page 118 in *The Mechanical Design Process*

[vii] The "Spiral Product Development at Syncromatics" case study