



ASAQ GOALBALL

MECH 497 – VALUE ENGINEERING

The report proposes effective improvements to the current court marking practice for the paralympic sport known as goalball. Primary methods of review rely on class knowledge of Value Engineering tools and analysis.

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Executive Summary

Mario Caron, and by extension the Association Sportive des Aveugles du Quebec Inc. (ASAQ) approached McGill University's value engineering class to solve problems associated with their court markings. The report is an account of the value engineering analysis performed by the team to address the client's needs.

Using value engineering fundamentals, a methodology starting at problem definition was used to best meet the client's needs. The client had been previously using expensive tape that had to be removed and reapplied several times a week: this resulted in high court set-up costs as well as discontent from the playing court owners as the tape often damaged the varnish during removal.

The focal point of the project is to substitute the marking method currently in use with one that maintains or increases performance (defined here as player experience), whilst eliminating the current undesirables (i.e. high cost, and court damage). With the next phases laid out by the organizational phase, the group moved forward with working on the functional needs of the client. This phase, critical to value engineering, allows the fundamental needs to be assessed, giving rise to needs that neither the team nor the client had considered previously. Next, the thought process transitioned into the creative phase where all sorts of ideas were proposed, ranging from the obvious (new tape) to the innovative (vibrational equipment embedded in shoes and gloves). The following phase evaluated the series of ideas using numerous tools such as: cost analyses, gut feel index, and Pugh matrices. Having narrowed the concepts down to one optimal idea, development of the idea into a physical solution took place.

Ultimately, the group elected to present one solution: new tape, in two form factors: budget and premium (both of these already sold on the market. All the analytical methods indicated that by using an alternative market solution, the group would not only reduce development costs, but would also best meet the client's demands. In addition, the fact the tape had much in common with the method previously in use allowed for little to no learning curve for the application of new court markings: an important consideration as something more complex may have proved difficult to learn in a short time for individuals with impaired vision. The two final products that meet the client's needs, and best replace the tape currently in use are: a filament tape (65% savings or \$43/game) and gaffer's tape (12% savings or \$8/game) with filament being recommended for practice and gaffer's for tournaments where the tape requirements are more stringent.

Background Information

Client Profile



FIGURE 1 - ASAQ OFFICIAL LOGO

Founded in 1979, l'ASAQ is an organization dedicated to building a world of sport for the visually impaired. The organization is involved in developing and promoting sports such as running, judo, swimming, goalball, and more. ASAQ has been officially recognized in 1990 as an organization in charge of sports for the visually impaired in Quebec. The ASAQ's contribution in this domain has provided numerous opportunities for the visually impaired in the field of sports.



FIGURE 2 - BLIND JAVELIN
THROWER

Game Origins

Goalball is a Paralympic sport for the visually impaired, originally designed in 1946 by Hanz Lorenze and Sepp Reindle for use in rehabilitation of those affected by World War II. The sport is designed specifically to address the challenges of visual impairment. Sport has proved itself to be an excellent therapeutic tool and improved the mental and physical health of billions of people around the world. Goalball is no exception. It was instrumental in rehabilitating and reintegrating numerous injured war veterans. The sport has now become internationally recognized after its introduction in 1976 as a Paralympic sport.

Game rules

There are two teams of three players positioned on opposite sides of the court with the goal of scoring the maximum number of points. Points are scored by rolling the ball into the opposing nets (much like in handball, though the ball must remain close to the ground). The game allows for players with partial vision of up to 10%. Though to even the playing field, the rules require all players to wear blackout goggles. In order to locate the ball, the players receive audio feedback in the form of bells that ring inside the ball as it moves. The figure below gives more insight:

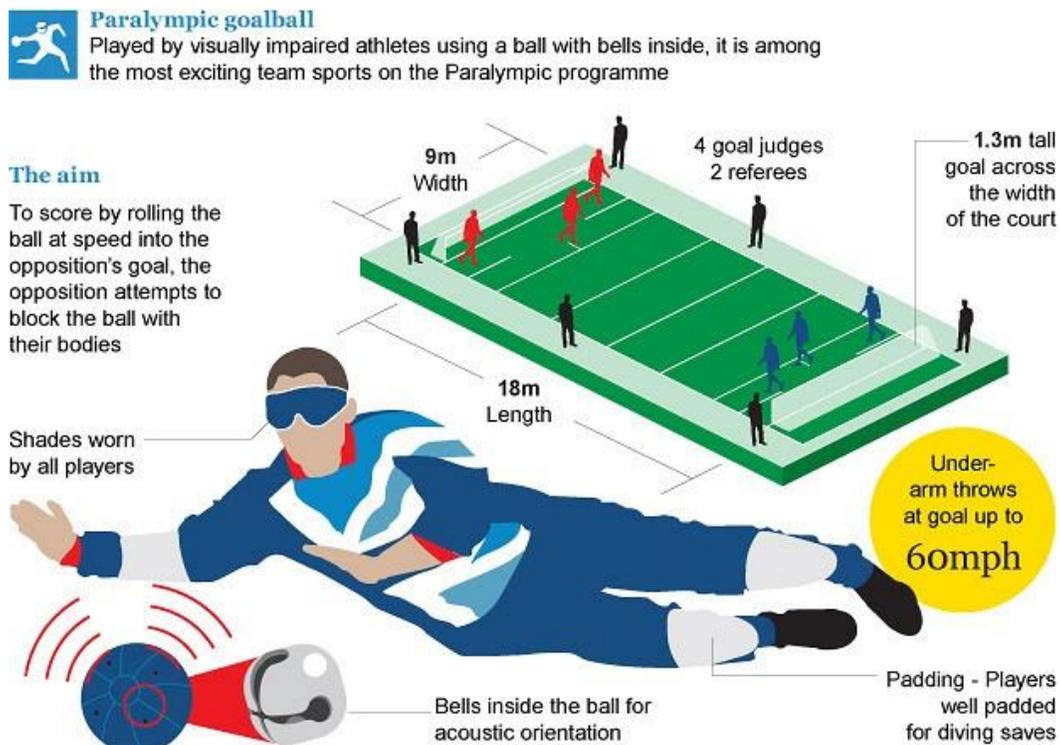


FIGURE 3 - GOALBALL RULES

Court Markings

A key component to the game is the setup of the court. In sports that allow for visual feedback, colorful lines on the court suffice. For Goalball, the challenge is to provide non-visual feedback, and this is currently achieved by means of a rope attached to the court with tape. The tape provides visual feedback to the referee, whilst the rope underneath it provides tactile feedback to the player. Players touch the rope with their shoes and hands during the game to orient themselves on the court.

Court markings for Goalball are cumulatively 110 meters (m) long, typically overlaid the top of volleyball courts as they possess the same dimensions. Court setup requires the installation of 110m of rope and tape before every game. While Paralympic stadiums have permanent court markings installed, teams practicing in Montreal have to share the court with other teams and other sports; therefore, the installed markings need to be removed after every game. The installation and removal of the current tape is presently a process that damages the court: when the tape is peeled off it often remove varnish or leave residue on the surface.

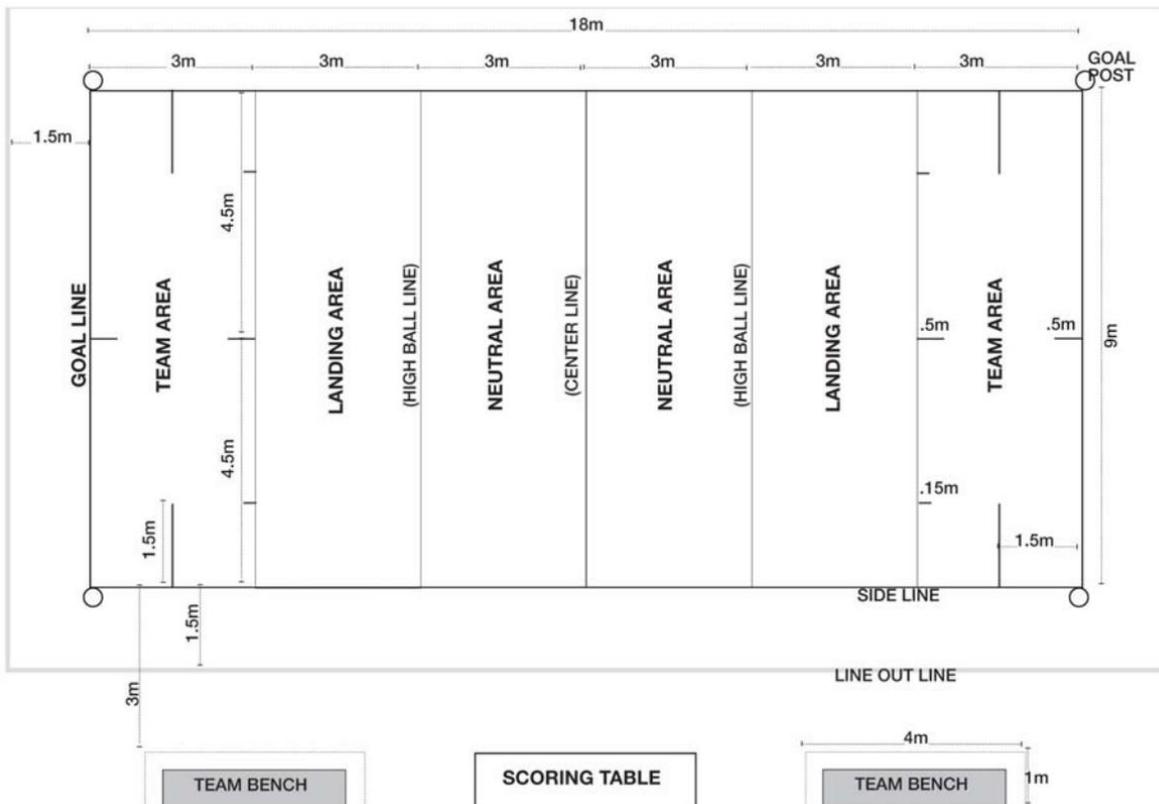


FIGURE 4 - GOALBALL REQUIRED COURT MARKINGS

Problem Definition

????

The team must to develop a solution that allows players to orient themselves on the playing field through non-visual means while keeping the lines visible to the referees. The problem is approached using value engineering analysis to guide the process of finding an optimal solution. The solution should address the client's problem of peeling varnish and leaving residue on the court. Ultimately, the team's goal is to maximize the benefits of the innovative solution and minimize all costs (monetary and otherwise) associated with it.

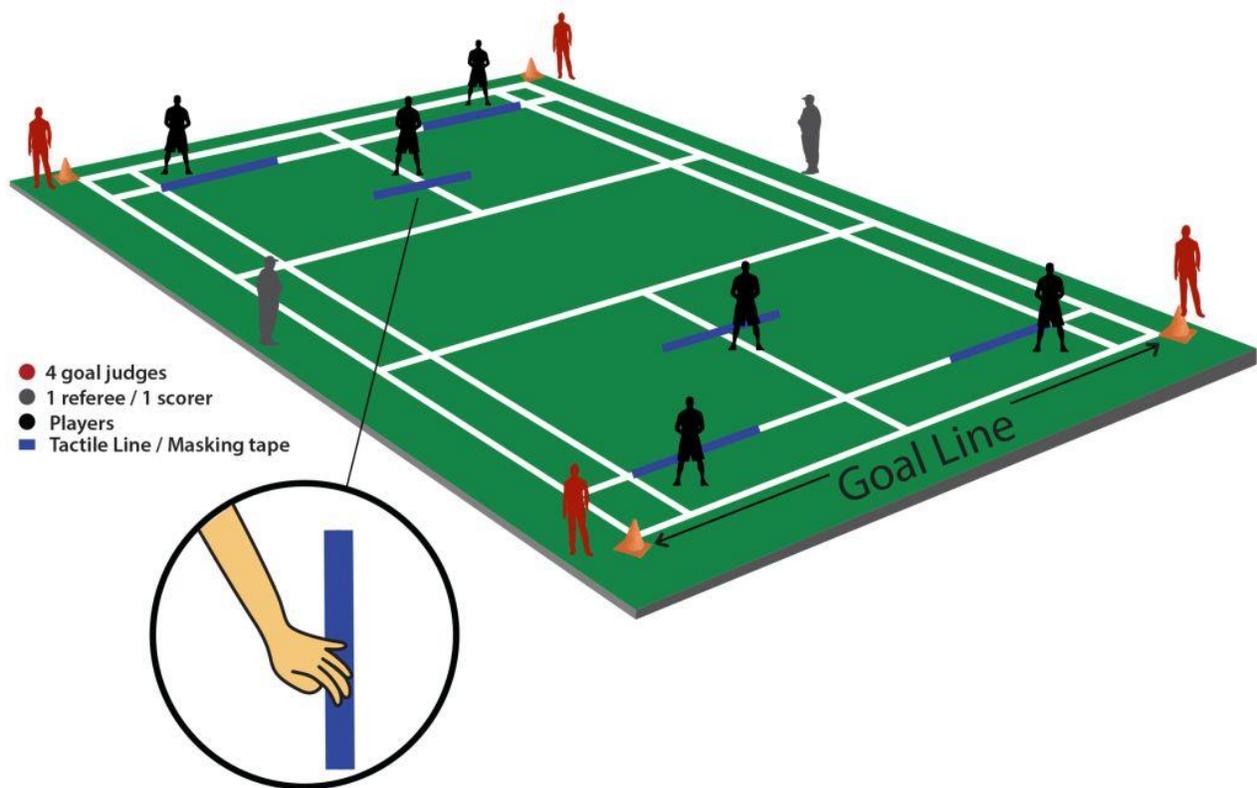


FIGURE 5 - GOALBALL GAME SETUP

Organization Phase

Value Engineering Process

For this project, the team followed the standard value engineering process outlined in the course pack and thoroughly explained during the lectures. Figure 5 provides a visual illustration of the value engineering phases.

The first step is Problem Definition in which the problem is worked out in detail with the client, and the objectives are clearly identified. Next, the Organization Phase is used to define the complexity of the project, the amount of information and time available, as well as resources supporting the project. Afterwards, the Function Analysis is performed to identify and understand the needs of the project by outlining the key functional components. The following phase: creativity, is reserved for brainstorming potential solutions and alternative means of meeting the functional requirements. In the Evaluation Phase, the proposed solutions are evaluated in terms of practicality and cost, zoning on the most valuable solution. After the idea is fleshed out in the development phase, the client is presented with the team's findings via a technical report and a summary presentation.

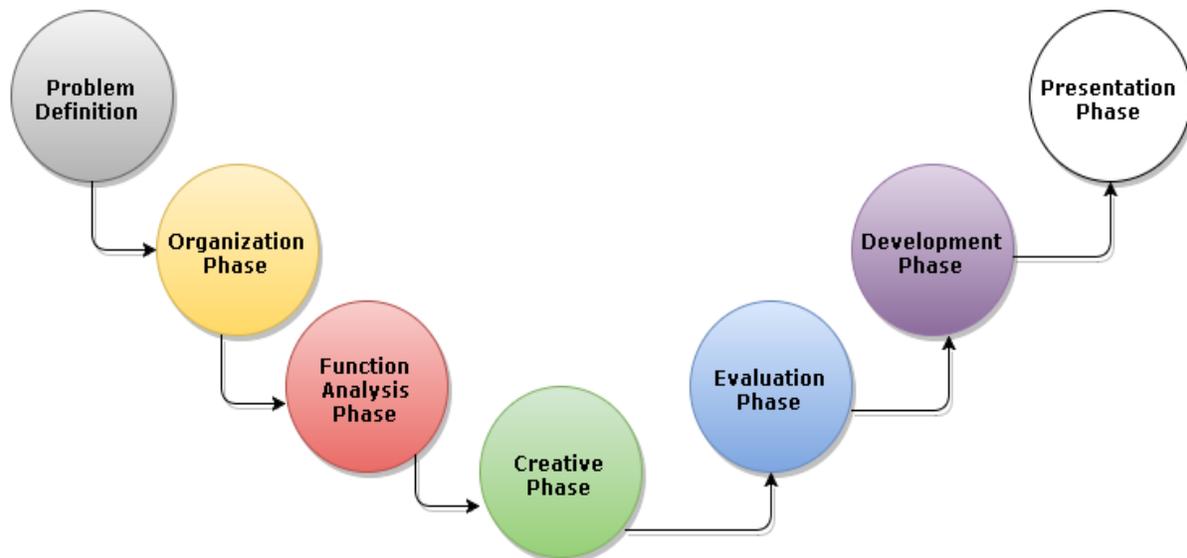


FIGURE 6 - VALUE ENGINEERING STAGES

Planning and Scheduling

The Gantt chart in Figure 7 provides insight into the team’s timeline and methodology. The scheduling is representative of the importance of each section. There are numerous phases with slight to significant overlap, this is most apparent in between the evaluation and development phases: this is because our early development pointed to errors in our evaluation where ideas once thought feasible proved too difficult to implement.

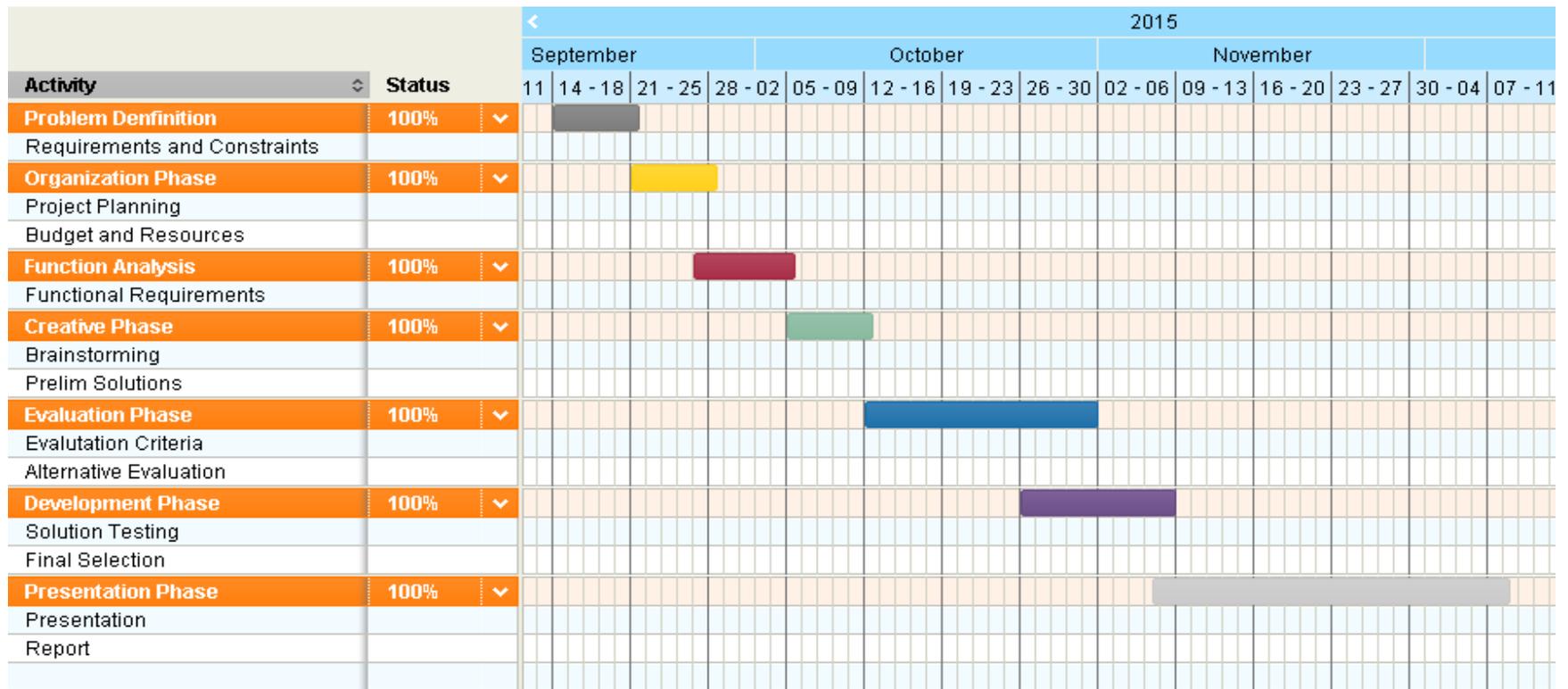


FIGURE 7 - GANTT CHART

Resources

Throughout the project, the team sought advice to arrive at the best solution. Figure 8 lists all of the stakeholders who contributed to the success of the project:

Stakeholder Name	Role	Coordinates
Mario Caron	Client	caronbeaupre@hotmail.com
Jamil Madanat	Member	jamil.madanat@mail.mcgill.ca
Matthias Rivollier	Member	matthias.rivollier@mail.mcgill.ca
Tarek Gouda	Member	tarek.gouda@mail.mcgill.ca
Vitalijs Arkulinskis	Member	vitalijs.arkulinskis@mai.mcgill.ca mail
Lucie Parrot	Advisor	lucie@martin-parrot.com
Paul Zsombor-Murray	Advisor	paul@cim.mcgill.ca
Joe Slanik	Advisor	josef.slanik@mcgill.ca jslanik@yahoo.ca
Vince Thomson	Advisor	Vince.thomson@mcgill.ca

FIGURE 8 - RESOURCES

Function Analysis Phase

Function Analysis is a technique used to identify and understand the needs of the client, (what must be accomplished, and on what level). The functions are described in two word definitions that outline the needs of the project. The two words used include an active verb and a noun.

The following six techniques were used to identify the functions:

1. Intuitive Research

This method allows the team members to brainstorm the functions contributing to the court marking requirements. As the name indicates, intuition is the only tool necessary for this part. The following functions were identified:

- Easy to feel
- Adhere to court
- Protect varnish
- Doesn't leave residue
- Stays put
- Visible to referee
- Resist water
- Resist abrasion
- Ability to re-use
- Orient players
- Define boundary

2. Environmental Analysis

In the environmental analysis, the team examined the environment of the court markings, and listed down the different elements as follows:

- Players:
They are constantly touching the markings with different body parts.
- Referees:
They use the markings to decide when a goal is scored, a ball is out of the field and when a player goes outside the allowed areas during a game.
- Rope:
It is a regulation in Goalball to have a rope under the court marking in order to orient players using tactile contrast.

- Ball:
The ball constantly crosses the court markings but its path should not be altered by the markings.
- Court ground:
The markings must remain on the court surface at all time.

After defining the different elements associated with the court markings environment, the team identified the functions related to these elements. Figure 9 illustrates the environmental analysis performed on the court markings' components.

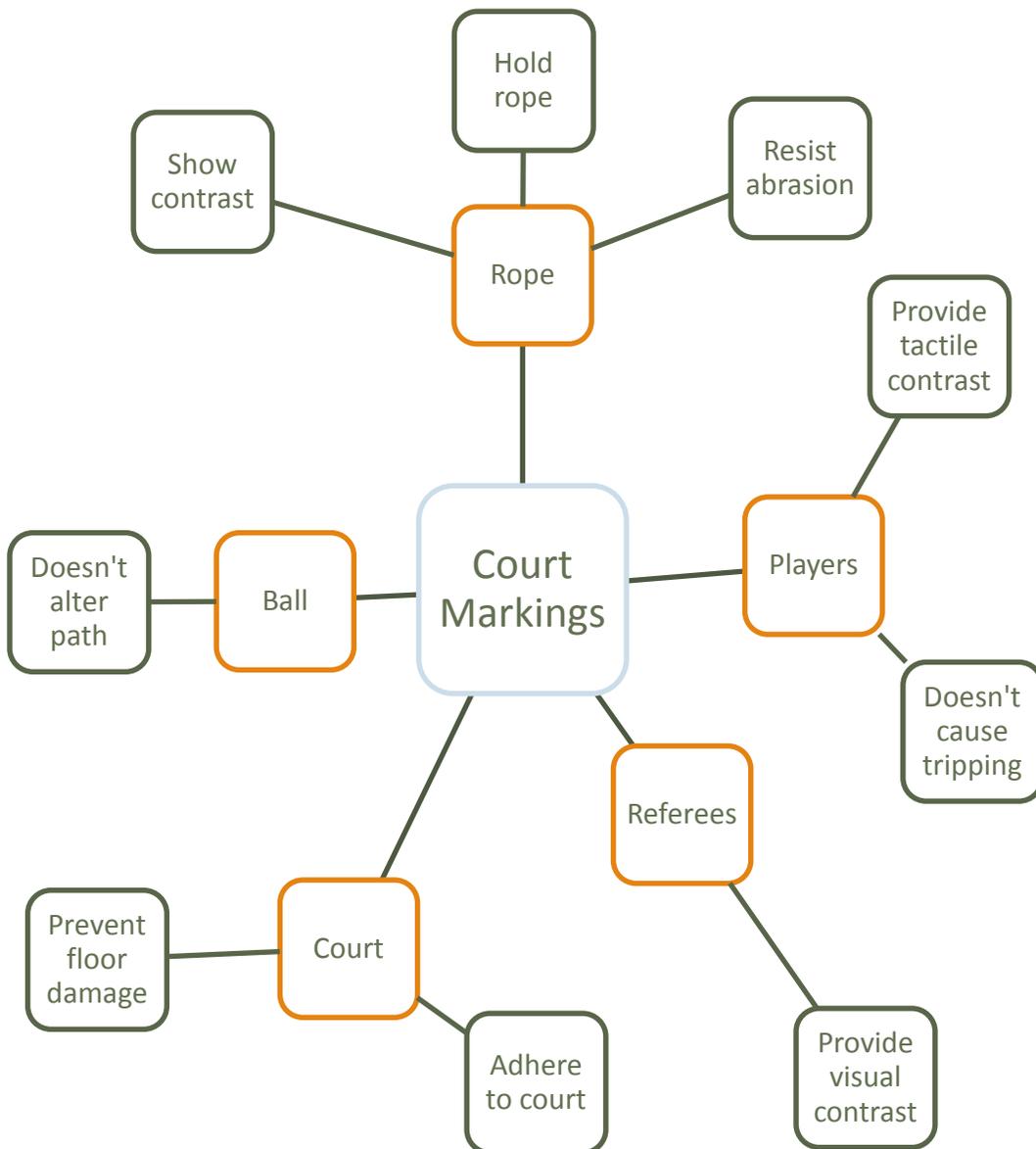


FIGURE 9 - ENVIRONMENTAL ANALYSIS

3. Sequential Analysis

In this step, the team studied the sequence of events that occur in order for a Goalball game to be played, and according to the client, the following stages were identified:

- [1] **Court Setup:** Before the game starts, the court markings are installed. This stage currently takes around 30 minutes.
- [2] **Game Time:** This is the stage at which the Goalball game is played; two teams competing, 3 players per team. [Is the game duration of interest here?]
- [3] **Court Markings Removal:** After the game is over, the court markings must be removed as the court is shared with other sports. It takes around 15 minutes to do so.
- [4] **Storage:** This stage is only in case a re-usable solution is found. Currently, this stage is not in action. does not apply.

Next, the required functions that the court markings should deliver at each phase were identified as follows:

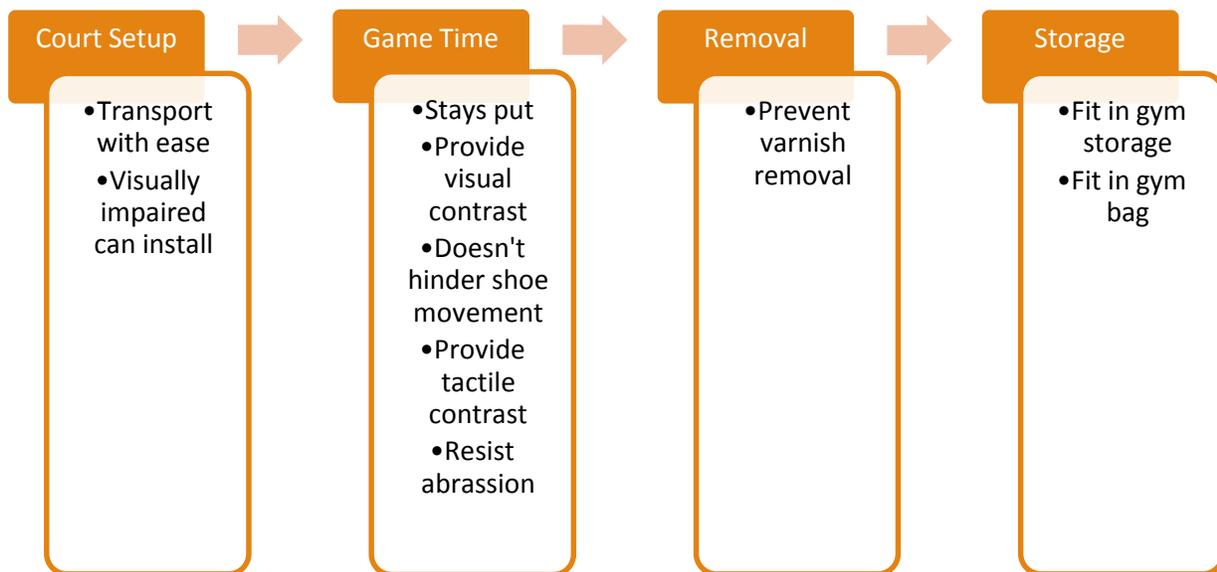


FIGURE 10 - SEQUENTIAL ANALYSIS

4. Movements and Efforts Analysis

Afterwards, the team identified the different movements and efforts that occur during a Goalball game, or during the set-up or removal stages, as follows:

- **Players' acceleration:** The players are constantly moving on the field, and touching the court markings with their various body parts or shoes.
- **Rope:** The rope under the court marking should be prevented from moving during the game.
- **Removal procedure:** the person removing the court markings after the game exerts considerable effort.

Next, the functions needed by the court markings that are related to the previous movements and efforts had been identified as follows:

- **Players' acceleration:**
 - ❖ Resist shoe friction
 - ❖ Resist pad friction
 - ❖ Resist peeling
- **Rope:**
 - ❖ Resist Movement
- **Removal procedure:**
 - ❖ Remain intact
 - ❖ Facilitate Removal

5. Reference Product Analysis

During this stage, the client provided a sample of the current tape used by ASAQ. The tape is the "Shurtape P-672". The characteristics of the current tape were examined using client feedback and team observation. The collected information helped the group determine the functions that the current tape is able to deliver successfully, and they are listed below:

- Resist abrasion
- Resist sweat/water
- Provide tactile contrast
- Resist rope movement
- Provide visual contrast



FIGURE 11 - SHURTAPE P-672

6. Standards and Regulations Analysis

Lastly, the team examined the rules and regulations of the Goalball game, which were provided by the client. It was found that the court markings have to satisfy three criteria to be used during Goalball games. The following functions were identified by this method:

- Satisfy width requirements
- Satisfy visibility requirements
 - ❖ Provide visual contrast
- Satisfy thickness requirements
 - ❖ Provide relief
 - ❖ Provide tactile contrast

FAST Diagram

After gathering all the required functions, the team started organizing and ordering the functions by putting them in a Function Analysis System Technique (FAST) diagram. Firstly, the team identified the main objective as “**Improve the inclusivity and sustainability of Goalball**”. Next, the question of ‘how to do so’ was asked, to consequently identify the following three main streams to be followed:

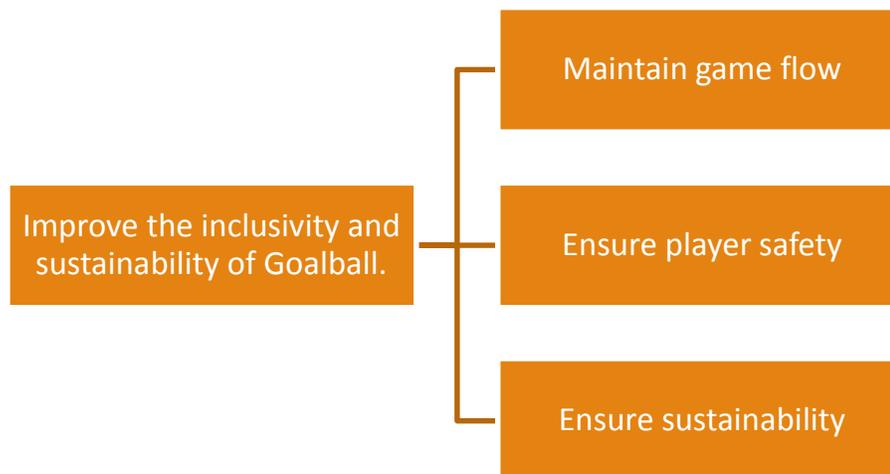


FIGURE 12 - FIRST 2 COLUMNS OF FAST DIAGRAM

To complete the diagram, an iterative process of asking the question of ‘how?’ was asked until all the functions were put on the diagram. To confirm that a function is placed in the right position in the diagram, the team went through the diagram backwards (from right to left), making sure to ask the question ‘why is this function needed’ whilst checking that the answer match the preceding function. Figure 13 shows the final FAST diagram.

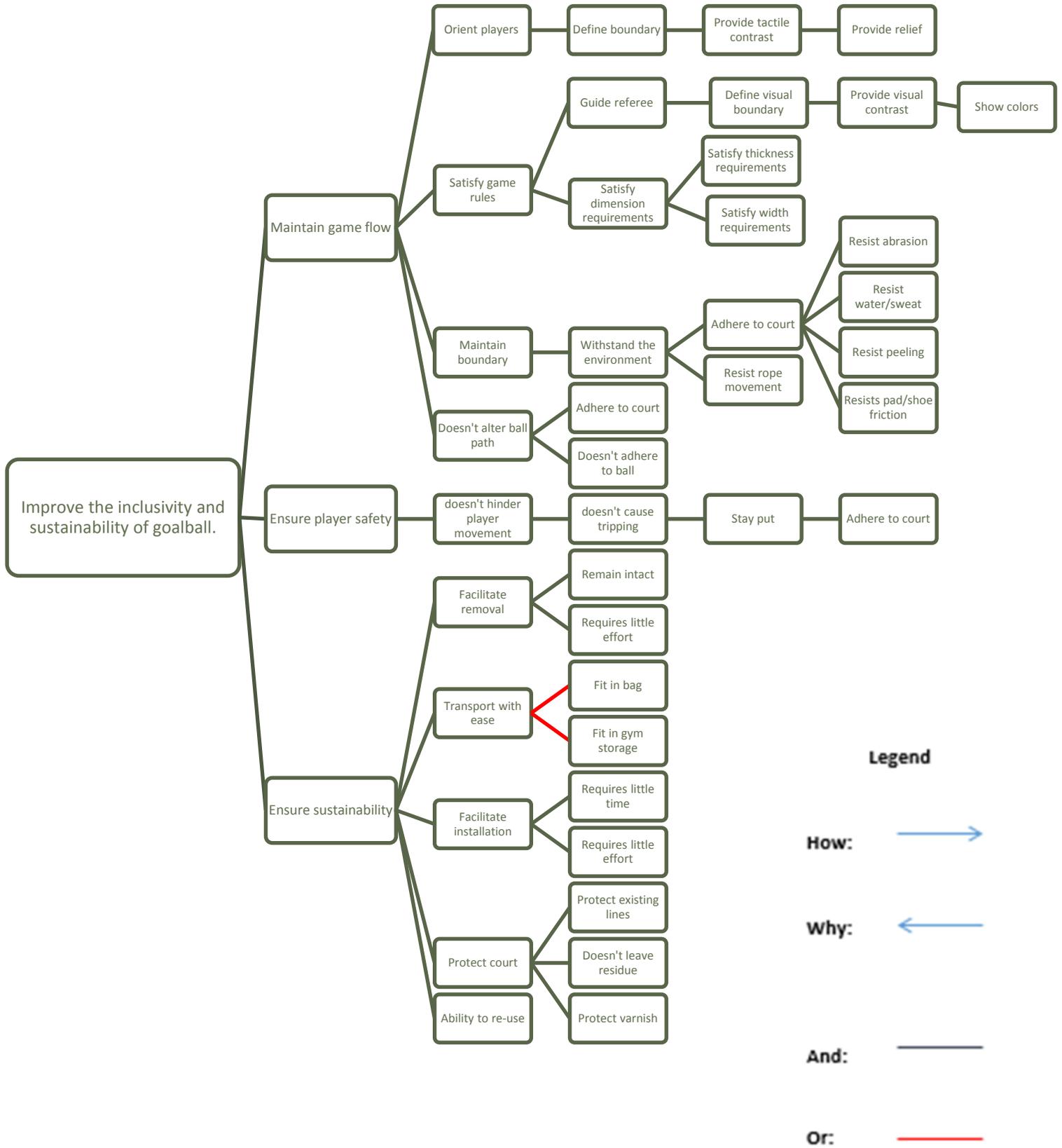


FIGURE 13 - FAST DIAGRAM

Function Characterizations:

After arranging the functions in a FAST diagram, the team gained a clear understanding of all the necessary functions the product must have. The last column of the FAST diagram represents all the detailed functions the product should ^{perform?} satisfy, and so characterization of these functions was ^{represents functions in more detail. Characterization ...} important.

The characterization was performed as follows:

measurable criteria

[Singular is "criterion".]

- A **criteria** that can be measured was given to each function.
- Each function was given a **level** (value) for its criteria that it needs to satisfy.
- The **flexibility** of each function was decided to determine how important is the function to the product, and whether or not it can be removed/substituted in order to save some of the costs or space. The following is the key to the different flexibility points given:
 - ❖ F0 = No Flex
 - ❖ F1 = Little Flex
 - ❖ F2 = Some Flex
 - ❖ F3 = Very Flex
 - ❖ % = % Flexibility
- Similar to flexibility, each function was given a level in the **hierarchy**:
 - ❖ 1 = Vital and Critical
 - ❖ 2 = Very Important
 - ❖ 3 = Important
 - ❖ 4 = Desirable
 - ❖ 5 = Nice to have

It is important to note that the client (Mario) decided the flexibility and hierarchy of each function, as they are most adept at defining their needs.

The following page shows the table summarizing all the function characterizations.

Number	Function	Criteria	Level	Flexibility	Note	Hierarchy
1.1	Provide Relief	Ability to feel	Feel through shoes	F0		1
1.2.1	Show Colors	Visibility	Referee can distinguish line clearly	F0		1
1.2.2.1	Satisfy thickness requirements	Thickness	0.003 (rope) + tape/alternate	17%		1
1.2.2.2	Satisfy width requirements	Width	0.05 m	20%		1
1.3.1.1	Resist skin abrasion	Durability	30 games	F2	Games last 1hr	1
1.3.1.2	Resist water/sweat	Water-resistant	Quality doesn't degrade with drops of sweat	F2		4
1.3.1.3	Resist peeling	Adhesion	Doesn't roll over unto itself	F1	8.43 N/10mm is current standard	1
1.3.1.4	Resist pad/shoe friction	Adhesion	Doesn't roll over unto itself	F1	8.43 is current standard	1
1.3.2	Resist rope movement	Adhesion	Can't move	F0	8.43 is current standard	1
1.4.1	Adhere to court	Adhesion	Can't move	F0	8.43 is current standard	1
1.4.2	Doesn't adhere to ball	Adhesion	Top side not adhesive	F0		1
2	Adhere to court	Adhesion	Can't move	F0	8.43 is current standard	1
3.1.1	Remain intact	Tensile strength	Strong enough not to fall apart in removal	F1	122.3 N/10mm is current standard	2
3.1.2	Requires little effort (removal)	Time of Removability	Easy enough for 14 year old to peel off	F1		3
3.2.1	Fit in bag	Weight & size	Fits in a sports bag, can be carries by 14y old	F1		3
3.2.2	Fit in gym storage	Weight & size	Fits in a gym storage room, can be moved by 14y old	F1		2
3.3.1	Requires little time	Time	Short set-up and removal time	F1	Less than 45 min	2
3.3.2	Requires little effort (Set-up)	Measurability	Easy to measure with measuring tape	F2		2
3.4.1	Protect existing lines	Removability & adhesion	Can be removed from court without ripping off old lines	F0		1
3.4.2	Doesn't leave residue	Cohesiveness	Removed from court in one piece without residue	F1		1
3.4.3	Protect varnish	Removability & adhesion	Can be removed from court without ripping off varnish	F0		1
3.5	Ability to re-use	Reusability	System that can set-up and taken apart multiple times	F3		2

TABLE 1 - FUNCTION CHARACTERIZATIONS

Cost Analysis

To begin, it is worth noting that the method followed to analyze the cost of the current court markings differs from the normal method recommended by value engineering. The reason is that the current court markings consist of only two components that satisfy all the mandated functions of the markings. The components are rope and tape.

The team decided to divide the cost analysis into fixed costs and variable costs. The fixed costs are one-time costs paid by the client because of the reusability of the items. The only fixed cost item in the current solution is the rope. The variable costs are the cost per game, as those costs will have to be paid each time a goalball game will be played (since the items cannot be reused). There are two variable costs in the current solution. The tape is the first one, as the tape is non-reusable and so each game new tape must be purchased. The second variable cost is the time taken to install and remove the court markings when each game is played. This is considered as a variable cost, since this time has to be spent by individuals each game, and it is relatively a long time (45 minutes according to our client).

The amount of tape and rope needed per game is equal to the total length of court markings specified by the Goalball rules:

- 2 strips of 18 meters
- 7 strips of 9 meters
- 4 strips of 1.5 meters
- 4 strips of 0.5 meters
- 4 strips of 0.15 meters

This totals to 107.6 meters of court markings. To add a safety margin, in case of waste tape or such, the team decided that **110 meters of court markings** are needed per Goalball game.

The current tape used by the client costs \$33.00 per roll of 55 meters. For 110 meters of tape, two rolls will be needed totaling to \$66.00 per game. In addition, the rope currently used, costs \$18 for the 110 meters, however this sum is only paid once at the beginning of every season as the rope is reusable.

Table 2 summarizes the cost analysis performed on the current court markings.

Number	Function	List of Components	Cost of Components	Total fixed costs	Total variable costs	Total Costs
1.1	Provide Relief					
1.2.1	Show Colors					
1.2.2.1	Satisfy thickness requirements					
1.2.2.2	Satisfy width requirements					
1.3.1.1	Resist skin abrasion	110 meters				
1.3.1.2	Resist water/sweat	of court				
1.3.1.3	Resist peeling	markings				
1.3.1.4	Resist pad/shoe friction	=				
1.3.2	Resist rope movement	110 meters	Tape = 2 x 33.00\$ = 66.00\$ per game			
1.4.1	Adhere to court	+				
1.4.2	Doesn't adhere to ball	110 meters	Rope = \$18.00 (once per season)	\$18.00 (Rope)	\$66.00 (Tape) +	\$84.00 +
2	Adhere to court	of rope			45 minutes	45 minutes
3.1.1	Remain intact					
3.1.2	Requires little effort (removal)					
3.2.1	Fit in bag		45 min set- up and take down			
3.2.2	Fit in gym storage	45 minutes				
3.3.1	Requires little time	for set-up				
3.3.2	Requires little effort (Set-up)	and removal				
3.4.1	Protect existing lines					
3.4.2	Doesn't leave residue					
3.4.3	Protect varnish					
3.5	Ability to re-use					

TABLE 2 - COST ANALYSIS

Creativity Phase

With the functions and costs properly delineated, the next stage of the value engineering method progressed to the creativity phase. The goal of this phase is to create conditions that foster the creation of innovative ideas. While creativity may be a fickle thing, there are ways to maximize people's ability to come up with all sorts of solutions. By having a facilitator guide the discussion, the group was able to brainstorm in the most effective manner. The first step was to have each team member brainstorm independently to think up ideas free from the influence of the rest. The facilitator then brought everyone together in a judgement free environment where any idea, no matter how creative or impossible, could be discussed. To this end, costs (monetary and time) and complexity were not part of the brainstorming discussion.

Once all the ideas were thrown out in the open, the team then altered each idea to best fit the client through the inputs of each member; having engineering students with a wide array of work experience proved to be of great use in having a wide spectrum of ideas and knowledge on various fields (stress, adhesives, etc). A number of the ideas are listed below.

- Different tape
- Permanent carpet
- Ribbon from ceiling
- Erasable marker
- Sonic system
- Vibrating shoes
- Rubber bump fastened by friction
- Rubber bump fastened by suction pumps
- Folded plastic parts fastened to the floor (cat's eyes)
- Schticky lines
- Non adhesive vinyl flooring
- Sprays on lines
- Textured paint on lines
- Roll-out heavy lines
- Silicone bottom pads and taped top
- Silicone bottom pads with suction holes

Many of these ideas can be traced to existing market solutions. The phase was concluded with 16 potential ideas that could be expanded upon to be evaluated in the following phases.

Evaluation Phase

With a rather large number of viable ideas in hand from the creativity phase, the team’s next mission was to whittle down the ideas that would meet the client's needs most effectively. There are numerous methods to evaluate ideas and compare them to another in an objective manner: Pugh matrix, merit & comparison charts, house of quality, etc. Ultimately, gut feel index, Pugh matrix, cost analyses, and merit charts were found to be right tools to select the optimal idea.

The gut feel index was performed first to sort out the ideas that weren’t even worth developing further. This is a great way to eliminate things that would clearly never satisfy the needs adequately, whether it be due to complexity, feasibility, or cost.

Idea	Is it non-desirable, why?	Gut Feel Index
Silicone bottom pads and textured tops	--	9
Schticky lines	--	9
Different tape	--	8
Rubber bump fastened by friction	--	7
Adhesive free vinyl flooring	--	7
Rubber bump fastened by suction	--	6
Permanent Carpet	--	6
Ribbons from ceiling	Feasibility is difficult (different ceilings), dangerous	4
Roll-out heavy lines	Risk of injury	4
Silicone bottom pads and textured tops	Implementation (vaccum/compressor too loud)	3
Sonic system	Out of scope (headphones not possible to hear ball)	3
Erasable marker	Feasibility (can't feel with feet)	2
Waxed based chemicals	Feasibility (too hard to remove)	2
Vibrating	Out of scope	2
Spray on lines	Feasibility (must be sanded off)	1
Folded plastic parts (cat's eyes)	Out of scope	1

TABLE 3 - GUT FEEL INDEX

Using the gut feel index as a springboard, the team elected to focus on four key ideas in order to make the best use of the short time window this project allowed. Their potential merits are discussed below along with their costs evaluate. Breakeven point was selected as the defining metric in cost evaluation over things like return on investment, since the rate at which games are

played varies with time, and breakeven was deemed more appropriate for things like using a new tape since there is no initial investment.

Idea 1 - Different Tape

The idea of using a different tape naturally arose as a solution to the problem thanks to its high feasibility: the setup would be identical, and the experience just as user friendly. The assumptions made here were that with a new tape would reduce the price, and would not require current methods to evolve in any appreciable way. On the flip side, simply using a different tape would not contribute to the sustainability of the solution, nor would it simplify the set-up and take down procedure (which already amounts to 45 minutes). One of the primary needs that are not met with the current tape is the ability to remove the marking without stripping the varnish off of the floor: a new tape would be chosen to meet this requirements. The impacts and risks here are minimal due to the similarity between the previous marking method. The key strength in this method is the ease of implementation since it would require no additional training, or time commitment to become effective.

Cost Summary	New Tape			Break Even Point
	Fixed Cost	Variable Cost (per game)	Total	
Original Cost	\$18.00	\$66.00	\$84.00	
Proposed Cost	\$18.00	\$20.00	\$38.00	1 Game
Savings	\$0.00	\$46.00	\$46.00	
Percent Savings	0.00%	69.70%	54.76%	

TABLE 4 - COST ANALYSIS: NEW TAPE

Idea 2 - Adhesive Free Vinyl Flooring

An adhesive free vinyl flooring, essentially a product that would be laid over where the lines would be and stay in place through friction was another key idea. After researching the different vinyl mats and their characteristics, it was deemed unfeasible to implement this solution due to main two reasons. First, it is too expensive to get rolls of vinyl flooring that will cover all the necessary lines. Goalball requires 110 meters of lining, while the cheapest possible vinyl mat available in the market is \$189/meter (though wider than we need it is also difficult to cut with a high degree of accuracy in long straight 18m lines), which results in a capital cost of \$20,790. It is

important to take into consideration that this is the price for the cheapest vinyl mat, which also has the lowest quality. The second feasibility issue of this idea, is concerned with placing the vinyl floor to the gym floor. The team for foresees that the thickness of the mats (minimum is 1/8 inches) could affect the movement of the players or the ball during the game. On the other hand, the main advantage of this idea is that it provides a permanent solution, and therefore will be cost-effective on the long run, and will cut a lot of the installation/removal time. Table 5 outlines the cost analysis of the vinyl flooring idea.

Cost Summary	Adhesive Free Vinyl Flooring			Break Even Point
	Fixed Cost	Variable Cost (per game)	Total	
Original Cost	\$18.00	\$66.00	\$84.00	
Proposed Cost	\$20,790.00	\$0.00	\$20,790.00	315 games
Savings	-\$20,772.00	\$66.00	-\$20,706.00	
Percent Savings	-115400.00%	100.00%	-24650.00%	

TABLE 5 - COST ANALYSIS : ADHESIVE FREE VINYL FLOORING

Idea 3 - Shticky Silicone Roller

The third proposed solution looks into finding a new adhesion method that offers reusability while preventing floor damage. The adhesive silicon system in the commercial product “Shticky” claims to have strong adhesive properties that can withstand high impact while facilitating removal and reusability by having hydrophobic properties.

After researching the product in more depth various drawbacks were identified. Consumer research showed that the strength of the adhesive silicon is lower than what is actually advertised. This means that extra effort needs to be made to ensure high adhesion to the gym floor. Since no product specifications or metrics exist this is a rather large drawback. In addition, in between uses the product must be cleaned and reactivated using large amounts of water. This results in significant costs: extra water usage, cleaning, drying and man labor.

Furthermore, the science behind this technology is inaccessible to the public which limits the group’s ability to study and implement this solution even further. Therefore, while this solution may look attractive in terms of reusability and practicality of implementation at first glance, in depth analysis clearly show that it is not that case. This solution will consume extra effort and cost that are considered unjustifiable, and for that reason, it is deemed unfeasible.

Idea 4 - Textured Silicone Pads

Textured silicon pads comprise the final idea, one where silicon with its high friction coefficient would stay fixed on the floor and with the addition of roughened surface could provide the tactile feedback necessary. One of the main distinguishing features of this concept is the ability to continue use for many years to come with one single purchase. Silicone can however become rather slippery when in contact with water, or in this case player sweat. Additionally, the thickness of the material will have to be at least 1/8th to resist the forces of the players throwing themselves on the lines in gameplay. Even at that thickness the silicone may give out, putting in question the durability of the product. Any thicker, and the marking would have too significant of an impact of ball movement. Below is the cost analysis looking at the financial value of the technology, provided no failures occur.

Silicone Bottom Pads & Textured Pads				
Cost Summary	Fixed Cost	Variable Cost (per game)	Total	Break Even Point
Original Cost	\$18.00	\$66.00	\$84.00	
Proposed Cost	\$700.00	\$0.00	\$700.00	11 Games
Savings	-\$682.00	\$66.00	-\$616.00	
Percent Savings	-3788.89%	100.00%	-733.33%	

TABLE 6 - COST ANALYSIS: SILICON BOTTOM PADS & TEXTURED PADS

The last tool in the arsenal to distinguish the ideas from one another is the comparison table and its accompanying merit-to-cost graph. The comparison table uses a variety of criteria that the team and the client have established to be important. The client then decided which criteria were most important by assigning different weights to each of them. With the weights established, each solution was graded out of 10 based on how well they met each criterion.

The Criteria

- Ability to feel
 - ❖ The ability of each player to feel the demarcation lines with their hands and through their feet without hurting themselves.
- Visibility
 - ❖ The ability of the referee to clearly distinguish the markings from the rest of the court.
- Thickness
 - ❖ The markings must meet the rules and guidelines set by the sport's regulatory body.
- Width
 - ❖ The markings must meet the rules and guidelines set by the sport's regulatory body.

- Durability
 - ❖ The ability of the markings to resist all the abrasive forces acting on it.
- Water-resistant
 - ❖ The ability of the marking to adhere to the court despite the player’s sweat
- Adhesion
 - ❖ The ability of the markings to adhere to the court through a game.
- Time of removability
 - ❖ How long it takes to remove the markings from the court so other sports can be played
- Weight & size
 - ❖ How easy it is to transport the markings from storage to the court
- Time of installation
 - ❖ How long it takes to put in place the markings before a game
- Measurability
 - ❖ How easy it is to lay down the exact right size for the markings
- Removability
 - ❖ The ability of the markings to be removed from the court without damaging the floorboards or requiring too much strength.
- Reusability
 - ❖ How sustainable and reusable the markings are

Having established the criteria necessary and weighted them, the team moved forward with the comparison table assisted by the client so that they could best match their needs to the proposed solutions.

Criteria	Weight	Current Tape	Different Tape	Adhesive Free Vinyl Flooring	Textured Silicone Pads
Ability to feel	10	10	10	10	10
		100	100	100	100
Visibility	9	8	8	9	8
		72	72	81	72
Thickness	6	10	10	4	3
		60	60	24	18
Width	9	10	10	5	3
		90	90	45	27
Durability	9	7	7	8	8
		63	63	72	72
Water-Resistant	1	6	6	10	9
		6	6	10	9
Adhesion	10	9	8	2	3
		90	80	20	30
Time of Removability	4	4	4	8	8

		16	16	32	32
Weight & Size	5	9	9	5	5
		45	45	25	25
Time of Installation	4	4	4	9	8
		16	16	36	32
Measurability	3	7	7	9	9
		21	21	27	27
Removability	9	3	7	8	8
		27	63	72	72
Reusability	6	1	1	10	9
		6	6	60	54
Cost for 50 Games		\$3,318.0	\$1,018.00	\$20,790.00	\$700.00
Total Points	612	638	604	570	

TABLE 7 - COMPARISON TABLE

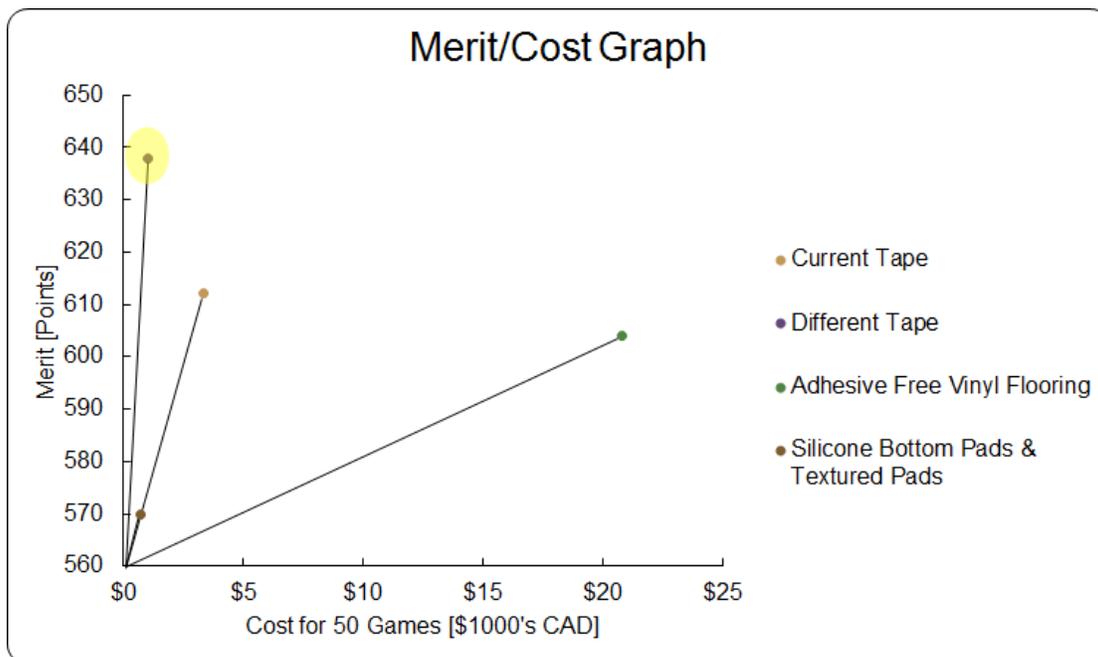


FIGURE 14 - MERIT/COST GRAPH

The graph is a great tool to visualize the value of each proposed solution. Everything to the left of the current solution has reduced costs and everything above meets the needs of the client better. The only solution that satisfied both the conditions was the different tape. After working with client extensively on the grading criteria, and evaluating the methods with the team independently this graph illustrates rather well the finding that the different tape will be the solution moving forward.

Development Phase

In the typical value engineering process the development phase differs slightly from the one the group went through. This is because rather than develop a new product, an already existing off the shelf solution would provide the best value because the development costs would be null, and the scale of production would lower the cost of goods and manufacturing significantly.

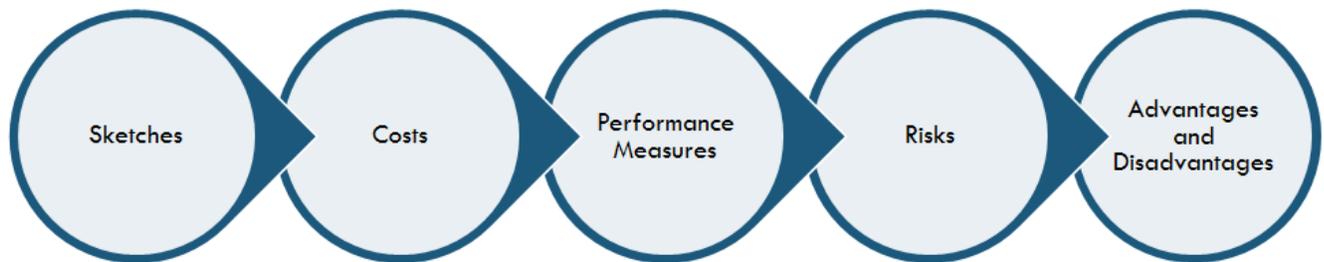


FIGURE 15 - DEVELOPMENT STAGES

Figure 15 shows the typical progression of the development phase. The group proceeded in the same way with the exception of the sketch phase which was omitted. In place of the sketch phase, market solutions had to be evaluated and compared to one another much like in the evaluation phase. A Pugh matrix was created for this purpose using mechanical properties such as tensile strength, elongation percentage, and adhesion to steel. Those properties were chosen since the market solutions have numerical data for these properties that lead to objective decisions. A number of calls were placed to various suppliers and manufacturers, and various tapes were suggested. Close to ten tapes were preliminary tested. Three tapes really stood out from the suppliers Scotch and 3M. The Pugh Matrix in Figure 16 compares the mentioned tapes:

Criteria	Shurtape P-672 (Baseline)	Scotch Bi-directional 8959	Scotch Unidirectional 897	Gafferpower Gaffer Tape
Adhesion	5	1	0	1
Tensile Strength	3	-1	1	0
Elongation %	2	0	1	1
Price	4	1	1	1
Ease of Application	3	0	0	0
No Residue	5	1	1	1
TOTAL	--	11	14	16

FIGURE 16 - PUGH MATRIX

The matrix shows two clear winners: the scotch unidirectional tap, and gaffer power's gaffer tape. These tapes would be used in much the same fashion as the current tape is. This solution is ideal for the client in as there will be no changes for the application, and the players will be familiar with this set up.

Presentation Phase

Theoretical evaluation of the solutions using a Pugh Matrix is followed by practical evaluation of the selected solution, done by looking at performance and cost in more detail. The team purchased a select number of tapes sold on the market based on their product specifications and how well they met the functional requirements. The client had been provided with the tapes for in situ testing. Test results as well as cost savings associated with each solution are presented, and finally a recommended problem solution is proposed.

Performance Testing

Current Tape

To begin, the current tape (Shurtape P-672) is set as a benchmark for evaluation. To recall its qualities, the current tape meets the performance requirements during the game by providing visual and tactile contrast, as well as adequate adhesion to resist impact. However, the major issue occurs when removing the tape after the game. At time of removal, the tape leaves residue marks that are difficult to clean and peels off the floor varnish as seen in figure 17:



FIGURE 17 - GLUE RESIDUE ON THE FLOOR AFTER TAPE REMOVAL

This leaves the court in an unacceptable condition for players who will be using it afterwards. Therefore the current tape is deemed unsatisfactory from a performance standpoint.

In addition, market research shows that the current price of the tape, at \$33 per roll, is a costly option compared to other alternatives in the market. The client uses two tapes per game at a rate of two games per week; thus, it is an excessively expensive solution in the long run.

Filament Tape

The first solution the client tested had been the Filament Tape and good feedback was received in terms of adhesion to the floor, tactile contrast for players, and protection of court varnish upon removal. However, the client reported two drawbacks inherent in this tape:

- Poor visual contrast for referees due to its semi-transparent characteristics.
- Difficult removability as the tape is made of uni-directional filaments that shear upon removal.

Although the tape has its downsides, it is inexpensive, at \$11.5 per roll, and has acceptable performance properties. Therefore, the team decided to keep the tape as a possible solution, and mitigate these issues using the following strategies:

- Using colored rope (instead of current white one) to provide visual contrast with the floor.
- Bending the tape's ends into a triangular shape to facilitate removability, as seen in Figure 18.



FIGURE 18 - USE OF COLORED ROPE AND TRIANGULAR TIP

Gaffers Tape

Second, the gaffer’s tape was tested by the client with very satisfactory results. This solution was well received by the client; as it resembles the current tape in terms of in-game performance, while being less adherent to the court, thus it doesn't damage the varnish upon removal. The gaffer’s tape provides both tactile contrast for the players, visual contrast for the referees, and is adhesive enough to resist players’ impact. The only drawback of this tape is cost: at \$29 per roll it is more expensive than the other tapes that were tested; however, it is worth noting that it is still cheaper than the current tape used by the client.

After the testing phase, the team conducted cost analyses for both solutions. The following section discusses the financial feasibility of implementing the solutions.

Cost Analysis

The cost analysis process starts with market research of alternative solutions and aims to evaluate long term cost savings for each solution. Table 8 shows a clear cost-effective advantage for the filament tape. The cost savings in the first game is calculated using the cost of two rolls per game plus the fixed price of the rope. Whereas, the cost savings after the first game accounts for the tape cost only, and excludes the fixed cost of the rope. The Filament tape shows 60% cost savings in the first game and 65% savings after the first game, compared to 9.5% and 12%, respectively, for the Gaffers tape.

Tape	<i>Shurtape 897</i>	<i>Filament tape (industrial)</i>	<i>Gaffers tape</i>
<i>Rope</i>	White	Pink	White
<i>Tape Price for 1 roll (55 m)</i>	\$33.0	\$11.5	\$29.0
<i>Rope Cost</i>	\$18.0 for 110 meters	\$10.5 for 138 meters	\$18.0 for 110 meters
<i>Variable costs (Tape) for 1 game (110 meters)</i>	\$66.0	\$23.0	\$58.0
<i>Fixed costs (Rope)</i>	\$18.0	\$10.5	\$18.0
<i>Total Cost for first Game</i>	\$84.0	\$33.5	\$76.0
<i>Savings in first game</i>	N/A	\$50.5 (60%)	\$8.0 (9.5%)
<i>Total cost for next games (after first game)</i>	\$66.0	\$23.0	\$58.0
<i>Savings/game (after 1st game)</i>	N/A	\$43.0 (65%)	\$8.0 (12%)

TABLE 8 - TAPE COST ANALYSIS

Proposed Solutions

The previous discussion shows a clear performance advantage for the gaffer's tape and an economical advantage for the filament tape. To maximize the trade-off between performance and cost, the team recommends the following two solutions.

Budget Solution

The team recommends using **filament tape** with the accompanying rope for practices. The client indicated that practices occur twice a week and have less visual contrast requirements. This way, the client can benefit from the long term cost savings (i.e. 65% after the first game), and minimize the consequences of current performance drawbacks. Figure 19 shows a picture of the Budget Solution.



FIGURE 19 - SCOTCH FILAMENT 897 & ACCOMPANYING ROPE

Premium Solution

The team recommends using the **Gaffers tape** for tournaments. The client indicated that tournaments are less frequent than practices and have stricter performance requirements (i.e. maximum visual contrast is needed for referees and audience). This way, the client can take advantage of the superior performance of the Gaffers tape while minimizing the cost in the long run. The Figure 20 shows a picture of the Premium Solution.



FIGURE 20 - GAFFERPOWER GAFFERS TAPE

Suppliers

For convenience, a list of suppliers for the mentioned parts can be found in the table below:

Item	Cost	Specs	1 game	Supplier	Contact	Comments	Link
<i>Gaffers Tape</i>	\$29.0	Black 0.051x55 m	\$58.0	AllStar Perf	1-269-463- 8000	Free shipping on Amazon.ca	http://amazon.to/1PKZ7aq
<i>Filament Tape</i>	\$11.5	Transpare nt 0.051x 55m	\$23.0	J Carrier	514-598- 9777 ext. 210 (Gordon)	More Adhesive - Free shipping for 2 cases	http://bit.ly/1leP7sH
<i>Colored Rope</i>	\$10.5	Pink 0.003x13 8m	\$10.5 (fixed)	Home Depot	1-800-628- 0525		http://thd.co/1ih60Si

TABLE 9 - LIST OF SUPPLIERS

Conclusion

In this report, the team describes the process undergone to define, analyze and solve the problem at hand using value engineering analysis. The problem entailed proposing an alternative marking system for goalball courts, while maximizing value and minimizing cost. The current marking system used by the client (ASAQ) is a highly adhesive tape that damages the court after removal, resulting in an unacceptable condition for other users. Moreover, market research showed that the current tape is a costly option when compared to other alternatives in the market. Therefore, a new solution had to be found.

To address this problem, the team carried out the value engineering analysis approach. The first step was problem definition which helped understand the client's requirements and needs. Following that, the team conducted functional and cost analyses to recognize the performance and financial needs of the project. The results established a basis for brainstorming solutions and selecting alternatives.

Next, during creativity phase, the team proposed various alternative solutions, and only a few feasible ones were carried over for in-depth evaluation. The selected solutions were: a new suggested tape, commercial sticky silicone (or Schticky), silicon pads (or suction cup), and adhesive vinyl flooring. Detailed evaluation, using Pugh Matrix and Merit/Cost Graph, showed that a new tape is the most feasible solution. The team performed thorough market research, as well as performance testing to select an adequate alternative tape. At the end, the team proposed two solutions to the client.

The first solution, known as Budget Solution, is the Filament tape with its accompanying rope. This tape matches the client's performance requirements, and offers 65% cost reduction after the first game. To minimize cost, the team recommends using this solution for practices as they are more frequent during the season.

The second solution, known as Premium Solution, is the Gaffer's Tape. This tape was the ~~most~~ preferred solution by the client due its superior performance criteria, in addition, the tape offers 12.5% cost reduction after the first game. The team recommends using this solution for tournaments as they necessitate strict performance requirements, and to minimize costs in the long run.

The team also recommends purchasing the tapes in bulk to take advantage of the free shipping and price reductions associated with bulk orders. A list of suppliers and their coordinates is attached in the presentation section of the report. The client is encouraged to contact them directly to receive the prices enlisted in the report.

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