Design of Transportation Process for Band Equipment

By,

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Introduction

In the music industry, generating revenue revolves around providing a service to customers. In a generation where piracy of music is at an all-time high, most modern musicians accept the touring life as the major source of income. The service in this case is providing entertainment through live music for a predetermined period of time. The process that goes into producing the final service is time consuming, strenuous and contains mostly non-value added steps. Local rock band *Louder Space* currently lacks a standardized method for transporting its gear to and from venues in an effective manner. As a result, the gear is in jeopardy of being damaged or misplaced and those transporting the gear are at high – risk of sustaining injuries. Such risks account for very large direct and opportunity costs that are to be factored into a band's budget.

The aim of this project is to design a safe and reliable process for transporting *Louder Space's* gear that requires minimal physical demand. Before the design process commenced, a list of design specifications were derived from customer requirements and physical constraints using techniques acquired in Quality Engineering (IME 430). Extensive research took place regarding existing portable storage mechanisms, ergonomics, human factors, and material properties in order to build off knowledge of Human Factors Engineering (IME 319) and ensure a sturdy, user-friendly product.

The design process was then broken down into the systematic approach steps from Facilities Planning and Design (IME 443). The result of this project provides a systematic process for transporting the gear, making use of lean methodologies adopted in Process Improvement Fundamentals (IME 223) in order to reduce the number of non-value steps involved. Furthermore, using Manufacturing Processes: Net Shape (IME 141) and Introduction to Design and Manufacturing (IME 144) skills, a model of the portable storage unit was developed to the specifications determined by the band, as well as certain limiting constraints. Once the customer approved the prototype, the product was broken down into a bill of materials from Production Planning and Control Systems (IME 410) and manufactured. Once the product was implemented, extensive analysis—similar to that of Industrial Costs and Controls (IME 239)—was done to determine the effectiveness of the project in terms of satisfying the objectives and meeting customer requirements.

Background

For over two years, *Louder Space* has been traveling up and down the California coast performing at venues ranging from San Francisco down to San Diego. As an entertainment company that survives off of providing a service to its customers, the band relies heavily on its gear to perform properly. But keeping gear organized and undamaged is often a challenge that the band faces on the road.

Poor material handling practices and organization of the equipment currently result in unnecessary material expenses, lengthy loading times, and high opportunity costs. First, band members break down their own gear so that it is ready to be loaded in. At this point in the loading process it becomes a free-for-all. The members pick up equipment at will leaving nobody accountable should something go missing or damaged. Generally, the larger gear goes in first followed by the miscellaneous items; however, locations for each item are not specified and tend to vary. With limited space in the bed of the truck, this lack of consistency often results in some of the gear not fitting properly or being physically compromised in some fashion. If something in the back needs to be removed, everything in front of it must first be removed. Once everything is loaded into the truck, there is no support for the fragile gear. This project addresses these issues and results in a product that improves all of these issues through methods learned in Industrial Engineering.

Literature Review

Every music group or individual musician needs an efficient equipment transportation method, whether that is for a marching band, famous singer, disc jockey, or local band's equipment. Each process is unique but there is an underlying objective for all "to provide an improved system and compact method for transporting instruments" [3] and equipment. The key components of choosing a band equipment transportation method include efficient organization and equipment movement flow, compatible ergonomics, accountability of the items, and safety of the materials. Most of the existing research covers large-scale music productions, mainly focusing on school marching bands and countrywide known artists. Although not directly applicable, much of the research done is influential to even smaller-scale local music groups.

"There are massive amounts of musical instruments and accessories to move around" [4] when setting up and taking down a concert or performance. "It is often the requirement of musicians, such as a musical or rock and roll band, that they must set up extremely quickly and must break down the equipment quickly" [3]. This doesn't leave much time for error, which is why the organization and flow process of moving equipment must be concrete. One step "in making loading and unloading easy is to pay close attention to the design of the truck or cart that carries the instruments" [4]. This way, the placement of the equipment can be organized in such a manner that fits the specific design. For example, certain "cases need to be easily accessible" [4] so they should be placed near the opening of the storage unit.

It is also very important to know “how it all comes off and goes back on" [9]. This way, not just the gear is organized, but the process is as well. Additionally, many “bands wrangle their sound and stage equipment themselves when they play gigs. In some bands, one or two members volunteer for that duty; in others, all the musicians are expected to lend a hand” [7]. By having an organized storage space, where everything has its place, members can help each other out more easily without confusion or misplacement of items. Ergonomics also plays a key role in supporting the efficiency of this process.

Ergonomics is defined as “an applied science concerned with designing and arranging things people use so that the people and things interact most efficiently and safely” [5]. When it comes to the transportation of band equipment, ergonomics encompasses a variety of design requirements. For one, "the cases need to be easy to use, and easily accessible… so that everything is in easy reach of the performer” [4]. It is also important to make sure the miscellaneous storage container “does not consume a large amount of space and is easy to store, yet is capable of transporting a plurality of band items” [3]. Some “trailers have the disadvantage of being very large and being hard to transport… as well as not being very compact” [3], which must be regarded. Easy-to-carry handles and durable construction are imperative features as well, in order to protect fragile gear from damage during haulage [1]. There are endless ergonomic designs to consider but there are other important transportation considerations, such as accounting for all of the band equipment.

The show can't go on if there are no instruments to play with. "You have to get the gear there, whether you truck it, fly it, or throw it under the bus" [9]. However, misplacement and loss of crucial band equipment happens to even the most famous music artists. For example, one New Year's Eve "Bernstein's company had loaded 20 trucks' worth of stage equipment and installments on an airplane, through a Paris connection and to the venue, with only misplacing 10 items. It was an impressive: logistical feat, but one of those missing pieces was the bass, which Paul McCartney desperately needed before taking the stage" [6]. Prevention of when "handlers forget to load items" [6] is essential to the survival of the band and the satisfaction of the audience. In order to avoid mishandling of items there are a couple measures that can be taken. When at all possible, the goods should be wrapped or containerized off site to ensure that all equipment is grouped together and accounted for [6]. Another simple fix to the problem is to create a checklist and take the time to complete it each time the band gear is packed or unpacked. "This includes not just your instruments and heavy equipment but—especially—the small stuff: amp fuses, batteries, spare cables, carpet for the drum kit, guitar stands, music stands, paperwork (set lists, chorded music sheets, arrangement notes), and so on" [7]. Each member can either be responsible for his or her own equipment or they can take turns carrying out a master checklist. Also, someone should always be responsible for double-checking the list(s). As well as accounting for all of the items, it is important to transport them safely.

“If [the cargo] gets there and it's damaged, it doesn't help” [6]. Damaged equipment is just as good as no equipment at all. Most instruments are sensitive and fragile, and even if they have their own case they must be treated with special care. “With all the special handling requirements for musical instruments and the unique logistical wrangling that goes into shipping bands” [6], transportation must be customized to make certain the gear is transferred safely. “How can you ensure that the equipment gets transported quickly and safely? Much depends, of course, on the kinds of storage cases you've picked” [4]. There are many things to consider when choosing a case. For example, it's particularly crucial to examine hinges before investing in a case by making sure they can take the wear and tear of traveling and can handle being opened in an unconventional setting, like on a slope. You also want strong construction around the hinges, so when the case is opened, that part isn't torn out [4]. As well as padding to keep the items from shifting and getting damaged. Choosing a safe transportation storage system and method goes hand-in-hand with choosing the correct one for every music artist.

Each music group is unique, as there are endless types and combinations of musicians, and each needs a variety of options when it comes to choosing the type of storage equipment. For example, “many bands are able to invest in a used van or SUV to transport the musicians and support crew, with an enclosed trailer in which to haul equipment” [7], whereas a disc jockey would be more likely to choose “a rackmount case on wheels designed to hold an entire DJ audio setup from mixers and CD players to amplifiers” [1] able to fit in the back of a car. What is needed,

therefore, is a unique system and method that provides certain transportation improvements, which fit the needs of each individual group, and can be customized using the key components of organization, ergonomics, accountability, and safety [3].

Design

Define Problems and Goals

The overall approach for the project design was developed utilizing a modified version of the systematic approach: Define, Measure, Develop, Evaluate, Select, Install. To begin the design process, a list of problems that address the existing design was created.

Existing Problems:

- Poor ergonomic flow and organization of equipment
- Little to no member accountability of items
- Waste in time during transportation
- Loss of money due to damaged or lost equipment

Some obvious constraints in the system are the dimensions of the bed of the truck used to transport the gear and the gear itself. These dimensions are fixed. The next constraint that was identified is that (although this is not always the case) only the four members of the band can be counted on as the physical labor force. For this reason, it was essential for the design to cater to limited "man power". Lastly, an aspect of the design that was initially overlooked was the width of a doorway. In the case of a product being implemented, the width of a standard doorway must be taken into account, which is approximately 2.5-3 ft., a dimension much more constricting than those from the bed of the truck.

Measure Existing Process

In order to quantify the current process issues, several engineering analyses were conducted. To better understand some of the issues that the band faced, cause-and-effect diagrams were created in order to identify the problem sources. The areas of most importance, such as losing, damaging, or forgetting gear as well as for unnecessary time spent packing the gear can be seen in Figure 1 and Figure 2.

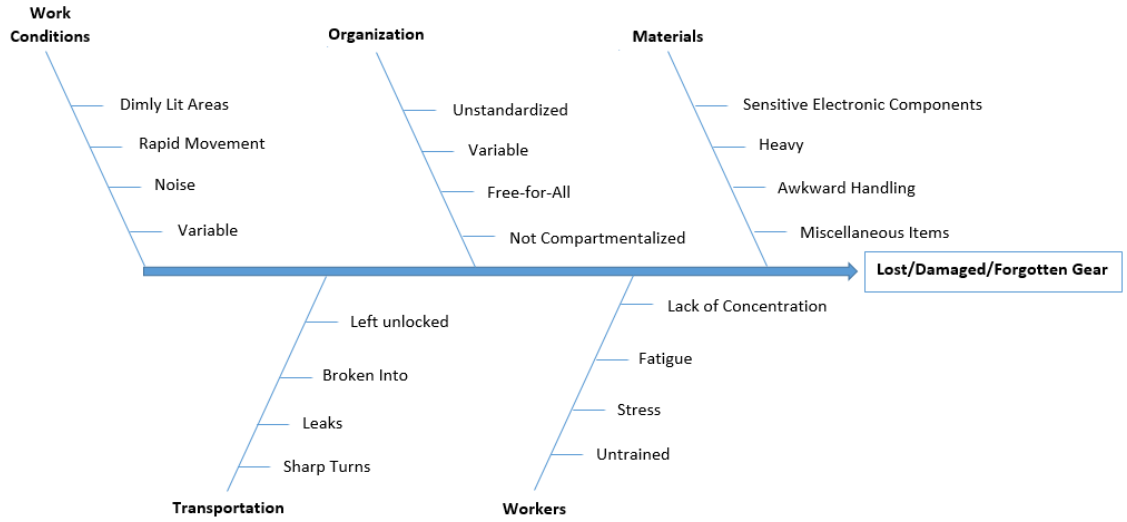

Figure 1: Cause-and-effect diagram used to target the root causes behind losing, damaging and forgetting gear.

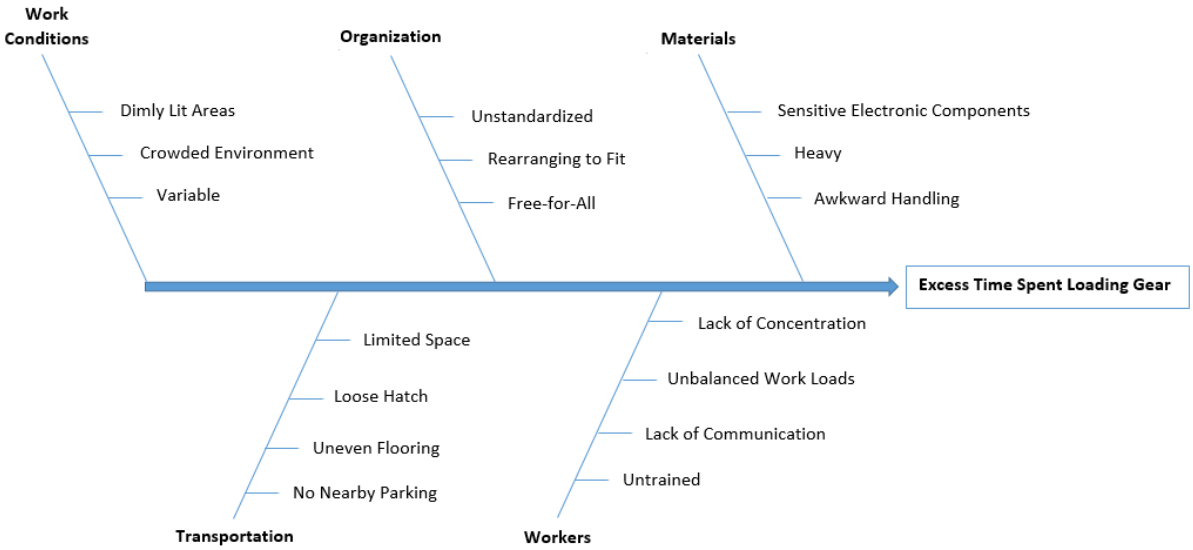

Figure 2: Cause-and-effect diagram used to target the root causes behind spending excess time loading the gear.

A house of qualities table was then created in order to determine more specific design specifications, which can be seen in Figure 3. The results were used as a guideline in the design process of the product.

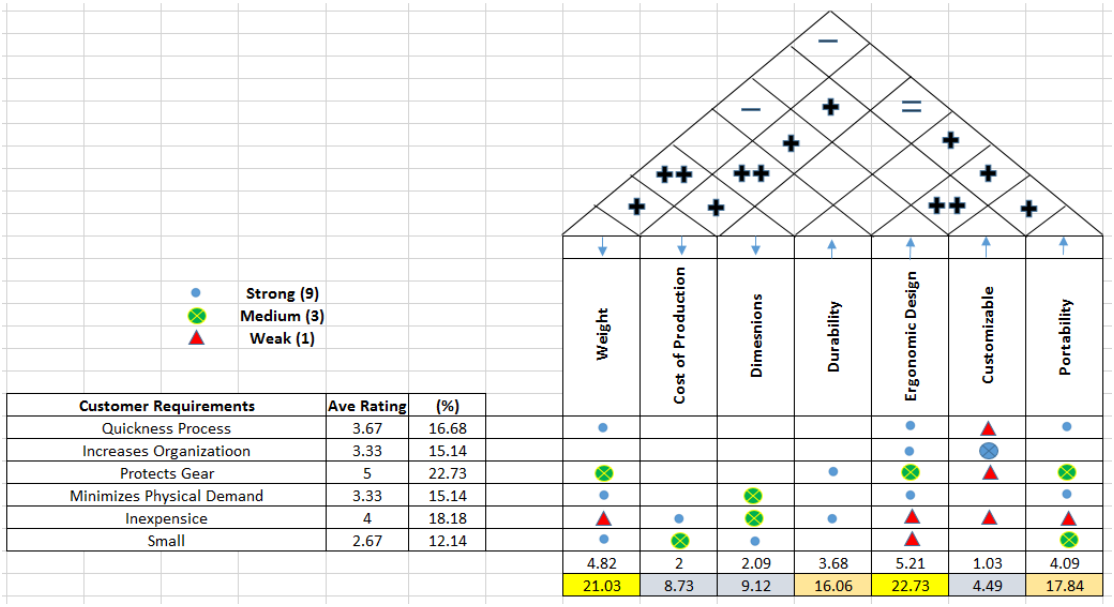

Figure 3: House of qualities table used in defining design specifications for the product.

Next, the entire process was measured using direct time studies. The time study for Chris (vocals) can be seen in Figure 4 and the others can be referenced in (Appendix A, Figures 5-7).

Operation:	Loading gear											
Observer:	Kent											
Operator:	Chris (Vocals)											
Element Description			Cycles						Summary Data			
			1	2	3	4	5	6	SUM	AVG	R	N
1	Walk to truck	R										
		T	5.33	7.08	9.31	5.27	8.4	8.62	44.01	7.34	1	7.34
2	Open hatch	R										
		T	26.52	19.25	22.61	17.87	24.56	20.62	131.4	21.91	1	21.91
3	Prop open with a broom stick	R										
		T	19.5	15.38	12.88	17.53	14.93	16.21	96.43	16.07	1	16.07
4	Walk back to gear	R										
		T	5.63	4.96	8.65	6.17	7.39	6.55	39.35	6.56	1	6.56
5	Pick up biggest item available	R										
		T	3.95	2.1	3.57	2.87	1.56	2.81	16.86	2.81	1	2.81
6	Carry item to truck	R										
		T	19.4	15.61	13.87	17.64	15.85	22.97	105.3	17.56	1	17.56
7	Place item in truck bed	R										
		T	54.78	49.27	47.8	40.31	43.67	51.79	287.6	47.94	1	47.94
8	Walk back to gear	R										
		T	9.89	6.35	12.3	8.49	19.43	7.81	64.27	10.71	1	10.71
9	Repeat until all available gear is loaded	R										
		T	308.8	369.2	403.2	321.9	396.04	310.55	2110	351.6	1	351.6
10	Inspect that all gear has been loaded	R										
		T	98.28	111.6	85.72	130.9	87.57	120.51	634.6	105.8	1	105.8
11	Wait for Oren to load in last of drums and Philip to insp	R										
		T	287.5	310.9	238.2	339.8	296.55	356.31	1829	304.9	1	304.9

* Observed Time = Avgerage Time
* Time in seconds

Total ST = 1099

Figure 4: Current-state time study taken of Chris (vocals) during the loading process of the gear.

The results of the current process time studies were to be used as a reference point in comparison with the proposed process time studies to measure improvement. The current process time studies revealed a significant imbalance of tasks amongst members. The process of loading the gear into the truck took, on average, 1,098.55 seconds (18.31 minutes). Foot traffic also played a role in magnifying the amount of travel time endured by each member. Based off of these time studies, a process flowchart was created for each member. The flowchart taken of Chris (vocals) can be seen in (Figure 8) and the others can be referenced in (Appendix B, Figures 9-11).

Location:	Practice Room								
Activity:	Packing Vox Gear								
Date:	January 25, 2014								
Operator:	Chris								
Circle Appropriate Method and Type									
Method:	(Present)	Proposed							
Type:	(Worker)	Material	Machine						
Analyst:	Kent								
Event Description							**Time (Sec)**	**Dist (ft)**	**Notes/Method Recommendation**
Walk to truck	○	➡	D	□	▽		9.03	18.58	Center point of room to truck bed
Open hatch	●	⇨	D	□	▽		26.95		
Prop open with a broom stick	●	⇨	D	□	▽		19.77		
Walk back to gear	○	➡	D	□	▽		8.07	18.58	
Pick up biggest item available	●	⇨	D	□	▽		3.46		
Carry item to truck	○	➡	D	□	▽		21.60	18.58	Foot traffic
Place item in truck bed	●	⇨	D	□	▽		58.97		Takes less and less time as bed gets
Walk back to gear	○	➡	D	□	▽		13.17	18.58	Foot traffic
Repeat until all available gear is loaded	●	➡	D	□	▽		432.47	222.96	6 repeats
Inspect that all gear has been loaded	○	⇨	D	■	▽		130.23		
Wait for Oren to load in last of drums and Philip to inspe	○	⇨	●	□	▽		374.9		
					Total =		1098.6	297.28	

Figure 8: Current-state flow process chart of Chris (vocals) during the loading process of the gear.

Pareto charts were then made in order to obtain a graphical summary of the results.

A Pareto chart for the current process non-value added tasks can be seen in Fig 12.

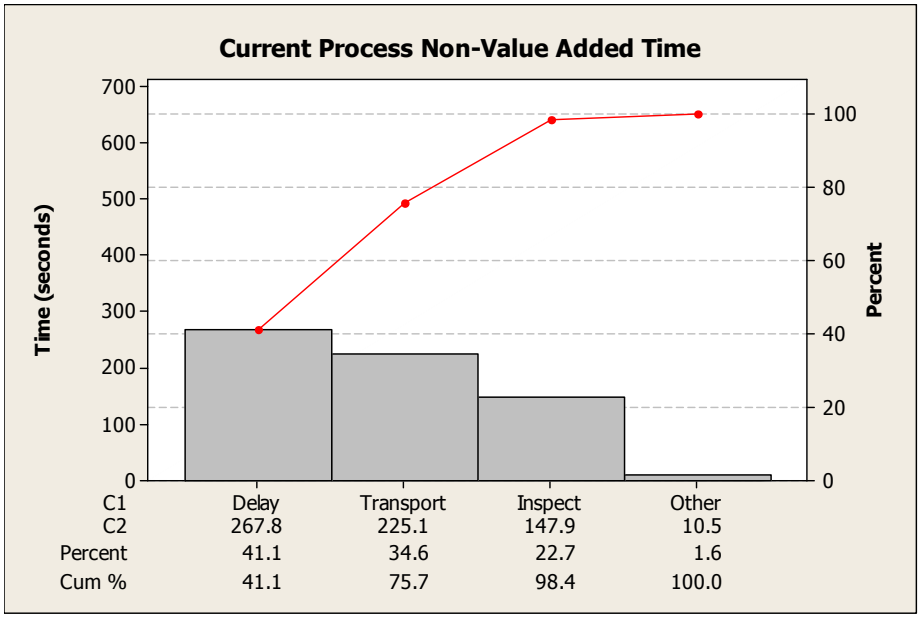

Figure 12: Current-state non-value added tasks.

As can be seen, delay and transport times consist of nearly 80% of all non-value added tasks making them targets for areas of improvement, Add inspection times into the mix and almost 100% of non-value added times are accounted for. Operation tasks were largely labeled value-added times or non-value added but necessary.

Lastly, all of the band's gear expenses for the last 2.5 years were compiled to create a Pareto chart, which can be seen in Fig 13. The Pareto chart was used to identify gear that is susceptible to being damaged or misplaced during the transportation process. Note, this does not include gear that is damaged while in use.

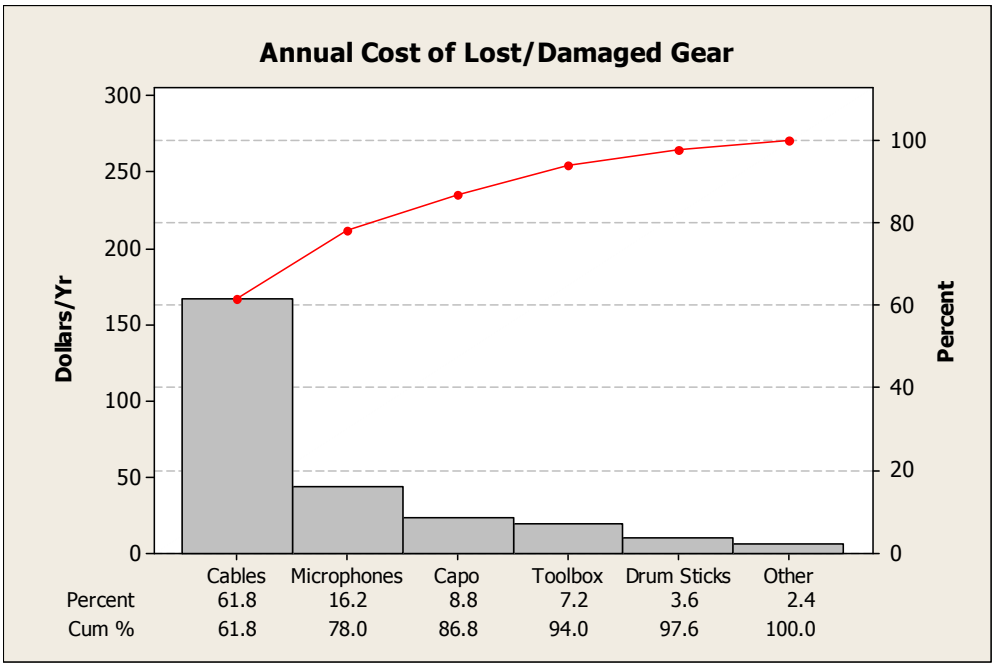

Figure 13: Current-state annual gear expenses.

Cables, which become tangled and crammed into backpacks, are damaged often. They are also easily confused with another band's or the venue's cables. Although cables only cost on average $15-20, the sheer volume that is lost or damaged

accounts for about 60% of annual gear-replacement costs. Other factors, however, play a role in the opportunity cost of losing an item. For instance, although Louder Space has lost only one toolbox since it formed, the loss temporarily stopped any maintenance from being performed on other gear.

Development of Alternatives

After a detailed account of the current process analysis, proposed solutions were defined and possible alternatives were generated.

Solution Goals:

- Develop an ergonomic, consistent and standardized transportation process
- Create a method of improving member accountability
- Come up with an approach to reduce time wasted during transportation
- Design a means for protecting the equipment in order to save money

It was determined that the implementation of a portable storage unit had the potential to help achieve all of the aforementioned solution goals. As the band has cases for most instruments including drums, guitars and basses, research was done as to what products currently exist that would most effectively satisfy Louder Space's needs. Leading retailers in industrial instrument cases such as *Gator Cases* offer utility cases ranging in the low hundreds of dollars (approximately $150-300), but these cases are small and would not suffice for band equipment such as cables or a toolbox [8]. *Road Cases USA* offers larger utility cases and more customizable

options with prices ranging in the mid hundreds of dollars (approximately $300-500) [2].

Alternative 1

The first design that was considered featured a very large, heavy-duty storage unit that would enclose all of the band's gear (see sketch in Figure 14 below). The benefits of this design stemmed from being able to load everything at once into the storage unit in an organized manner and then transporting the storage unit to the truck, greatly reducing travel distance. Furthermore, the enclosure would be custom built to fit the bands gear, helping to protect the gear against harmful conditions.

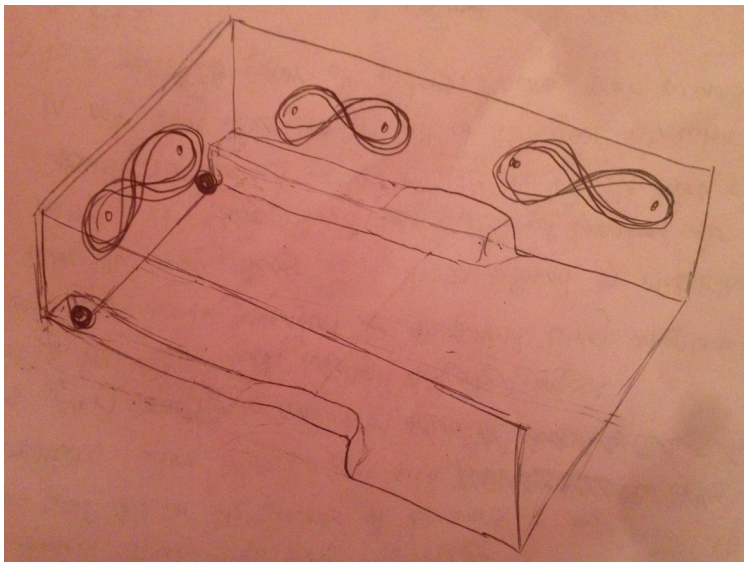

Figure 14: Sketch of the product design for alternative 1: An all-encompassing portable storage unit, which fits all of the band's gear.

A reusable Master Checklist would be placed on the door of each compartment with a list of everything that belongs inside, which would be checked-off by the member's initials responsible for loading the equipment. This simple yet effective technique

serves as a preventative measure to help keep track of gear but would also be used to hold one another responsible for missing items. However, several drawbacks to this product made it a less-than ideal design. First off, there are no existing products like this on the market, and to manufacture such an enclosure would be far too costly. Cost aside, fitting so much gear into an enclosure that would fit the constraints previously identified (i.e. doorway width and truck bed dimensions) would be a challenge. Even if successful, it would be a huge physical burden due to the massive weight of the unit, which would prove useless to the band. From here, it was decided to brainstorm alternatives where the large gear is transported separately from the unit.

Alternative 2

In order to allocate the gear items to be transported individually, the equipment would be differentiated into categories indicating which items need to be stored and protected inside of a smaller unit (see sketches in Figure 15 below) and which items should remain outside. This alternative would also include the Master Checklist from Alternative 1 for the band to use.

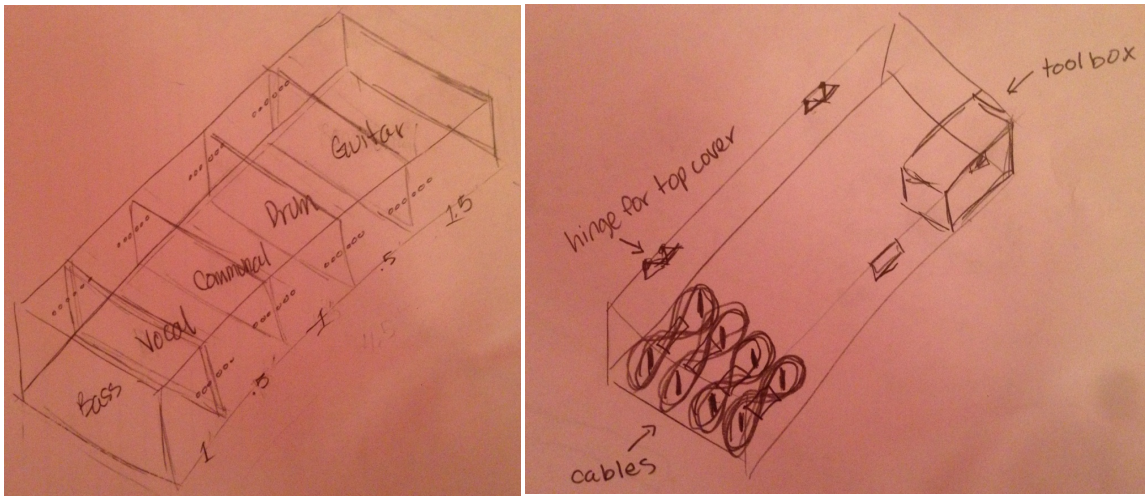

Figure 15: Sketches of the product design for alternative 2: A small enclosure to transport miscellaneous gear.

The design of this process features a much smaller enclosure, strategically targeting miscellaneous gear, and focuses more on the process as a whole through the organization of the truck bed. Although similar products exist, it was determined that it would be cheaper to purchase the materials needed to build the product and manufacture the product in-house. This design is a much more cost-effective approach than the first alternative design, offers protection only to the items that require extra protection, is much more practical, will limit travel distance through the implementation of a more sound method, and will greatly improve the organization of the gear.

Evaluate Alternatives

To compare the alternatives using an Analytical Hierarchy Process (AHP), a Pairwise Comparison chart (see Figure 16 below) was created in order to rank the relationships between low cost, good organization, feasible size, adequate protection, and the travel distance saved. Accountability was not included due to the same values for each alternative. The Score Key shows the description of the scores represented in the comparison chart.

Pairwise Comparison					
	Cost	Travel	Organization	Size	Protection
Cost	1.00	0.33	0.20	0.50	0.25
Travel	3.00	1.00	0.20	0.50	0.25
Organization	5.00	5.00	1.00	0.33	0.50
Size	2.00	2.00	3.00	1.00	0.50
Protection	4.00	4.00	2.00	2.00	1.00
Sum	15.00	12.33	6.40	4.33	2.50

Score Key	
Description	Number
Equally Important	1
Somewhat Important	2
Important	3
Significantly Important	4
Extremely Important	5

Figure 16: Pairwise Comparison Chart

Then a Standardized Matrix (see Figure 17 below) was created in order to calculate the percent importance of each factor. For example, cost has only 6.8% importance in the final decision, organization has 23.44%, and so on.

Standardized Matrix							
	Cost	Travel	Organization	Size	Protection	*Sum*	*Percent*
Cost	0.07	0.03	0.03	0.12	0.10	0.34	6.81%
Travel	0.20	0.08	0.03	0.12	0.10	0.53	10.55%
Organization	0.33	0.41	0.16	0.08	0.20	1.17	23.44%
Size	0.13	0.16	0.47	0.23	0.20	1.20	23.90%
Protection	0.27	0.32	0.31	0.46	0.40	1.77	35.30%
Sum	1.00	1.00	1.00	1.00	1.00	5.00	100.00%

Figure 17: Standardized matrix.

Next, the alternatives (see Figure 18 below) were ranked using the same score key. In order to find the Weighted Alternative Scores (see Figure 19 below), the percentages above were divided by 100 and multiplied by the alternative scores.

Alternative Scores		
	Alt 1	Alt 2
Cost	0.3	0.9
Travel	0.2	0.8
Organization	0.9	0.8
Size	0.3	0.9
Protection	0.6	0.5

Figure 18: Alternative scores

Weighted Alternative Scores		
	Alt 1	Alt 2
Cost	0.0204	0.0612
Travel	0.0212	0.0848
Organization	0.2106	0.1872
Size	0.0717	0.2151
Protection	0.2118	0.1765
Total	0.5357	**0.7248**

Figure 19: Weighted alternative scores.

Select Alternative and Design Final Product

Due to its higher weighted score of 0.72, compared to 0.54, Alternative 2 was chosen. In order to design this alternative, it was broken up into three elements: design of the large items (flow process), design of the small items (portable unit), and a master checklist for each.

First, interviews with each band member were conducted in order to categorize their equipment into small, miscellaneous items that they would like to go in the portable unit and large items that can stay out and be transported individually (see Appendix C, Figures 20-23). Next, each of the "out" items were packaged up into their appropriate cases and another set of interviews were conducted in order to begin on the flow process design of the large items. Using the knowledge that the drum equipment takes up the most space and time to set up, it was determined that the guitar and bass gear were to be grouped together (see Figure 24). The LIFO (last in, first out) method of categorization was explained to each band member, and then

which of the large items should be put in first and which last was determined (also seen in Figure 24).

Number	Description	Drum vs. Bass/Guitar	First vs. Last
1	Snare Drum	Drum	First
2	Cymbal Case	Drum	First
3	14" Tom Case	Drum	First
4	12" Tom Case	Drum	First
5	Miscellaneous Drum Box	Drum	First
6	Amp head	Bass/Guitar	First
7	Fender 4x12 Cab	Bass/Guitar	First
8	Lower Cabinet Speaker	Bass/Guitar	First
9	Vox ACH50	Bass/Guitar	First
10	Mounts	Drum	Last
11	Guitar Rack	Bass/Guitar	Last
12	16" Tom	Drum	Last
13	Bass Drum	Drum	Last
14	Guitar	Bass/Guitar	Last
15	Upper Cabinet Speaker	Bass/Guitar	Last
16	Pedal Board	Bass/Guitar	Last
17	Guitar	Bass/Guitar	Last
18	Bass	Bass/Guitar	Last
19	Pedal Board	Bass/Guitar	Last

Figure 24: List of large gear ranked with LIFO

An afternoon was then spent organizing the large equipment into the truck, using the two categories of “Drum vs. Bass/Guitar” and “Last vs. First”. After much trial and error, the most efficient and equipment-safe packing flow can be seen in the two photos below. The drum equipment is shown on the left and the bass/guitar is on the right, with the first-in items shown in Figure 25 and the last-in in Figure 26 below, with the corresponding numbers shown in Figure 24 above.

Figure 25: First-in items in standardized locations.

Figure 26: Last-in items in standardized locations with extra space for portable storage unit.

Finally, the remaining space circled in Figure 26 above, shows the space purposefully left for the portable storage unit. The small items' overall size was previously measured and space was allocated in the design above.

The unit size was determined using engineering anthropometry and the space required for the items. The normal and maximum arm span working areas are 47''-59'' and the necessary length of the box in the truck was 42''. Since 44'' (42'' with a tolerance of 2'') fell within the normal working area of a person, it was decided to be the length of the unit. Next, the required width of the unit was measured to be 15'', which falls within the average person's frontal reach of 22''. The space allocated for the unit was 20'' from the end of the truck bed, where tolerance of 5'' was added to the width. Finally, the height was determined using the 50^{th} population percentile elbow height of both males and females (42''). The handles of the unit were to be placed, with a tolerance of 2'', at 40'' from the ground. The truck bed sits at 32'' high and 8'' was not a tall enough height for the items in the unit, so it was determined to be 12'' instead.

Next, the unit was designed to be compartmentalized into 5 areas: one for bass, one for guitar, one for vocals, one for drums and one section for communal items. Adjustable areas for compartments are ideal so that the product is useful to other bands as well and therefore has the potential for being mass-produced. Figure 27 shows images of the design that were developed.

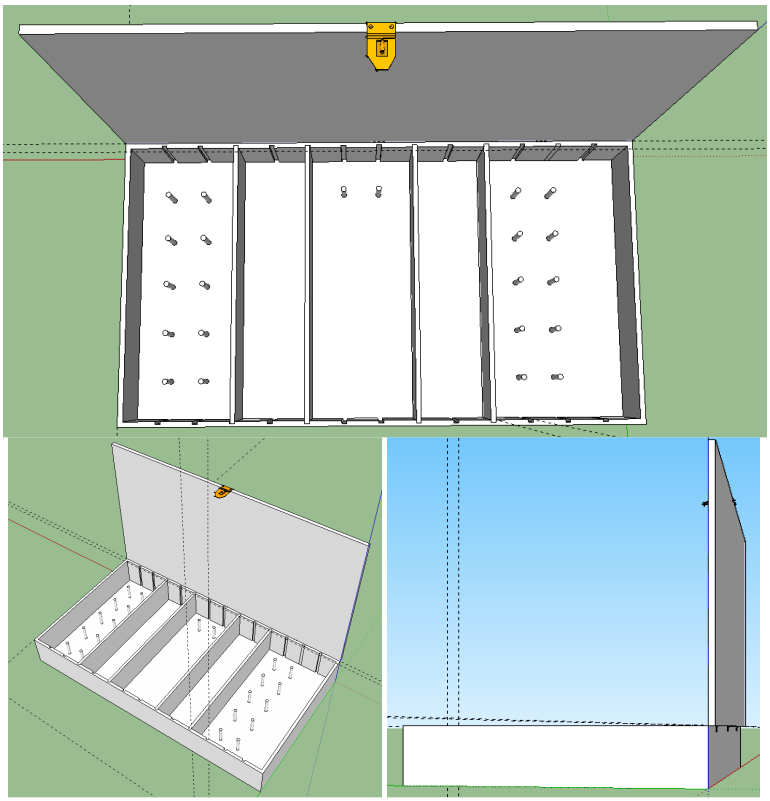

Figure 27: 3D model of the portable storage unit for miscellaneous items.

The compartments were organized such that the communal area is in the middle since everyone would need to access this area. The area for the guitar and the area for the bass on the ends, as they contain the most similar items that could easily cause confusion or be mistaken for each other. The vocal and percussion compartments are to be in between the ends and the center communal areas. Key features of the product include adjustable walls to allow for more or less space allocated to different compartments, pegs to allow for the wrapping of cables, and foam cutouts to hold items in place while also offering protection against harmful conditions.

Lastly, a master checklist for the large items, the portable storage unit and miscellaneous drum items were made in order to hold the members accountable and help prevent the loss of equipment. The checklists were made to be reusable and environmentally friendly by laminating them and using an erasable marker. Also, they were designated to be stored in the communal compartment of the storage unit, attached with a string so that they don't get misplaced as well. These checklists can be seen in Figures 28 -30.

Portable Unit Checklist				
Name	**QTY**	**Each/Set**	**Category**	**Initials**
Mic	2	Each	Vocals	
Mic to PA Cables	4	Each	Vocals	
Tambourine	1	Each	Vocals	
Set Lists	4	Each	Vocals	
Guitar Pick	10	Each	Guitar	
Guitar Strings	2	Set	Guitar	
Guitar Capo	1	Each	Guitar	
Surge Protector/Extension Cord	1	Each	Guitar	
1/4" Guitar Cables	2	Each	Guitar	
Power Chord for Amp	1	Each	Guitar	
Guitar Strap	2	Each	Guitar	
Wire Cutters	1	Each	Guitar	
Drum Sticks: ProMark 721	2	Set	Drum	
Drum Light Controller/Power Supply	1	Each	Drum	
Bass Pick	15	Each	Bass	
Cables	5	Each	Bass	

Figure 28: Checklist for portable storage unit items.

Large Item Checklist				
Name	**QTY**	**Each/Set**	**Category**	**Initials**
Straight Mic Stand	1	Each	Vocals	
Bent Mic Stand	1	Each	Vocals	
Vocal Speakers	2	Each	Vocals	
PA	I	Each	Vocals	
PA Stands	2	Each	Vocals	
Guitar	2	each	Guitar	
Guitar Pedal Board	1	each	Guitar	

Vox ACH50	1	each	Guitar	
Fender 4x12 Cab	1	each	Guitar	
Guitar Rack	1	each	Guitar	
Bass Drum Pedal	1	Each	Drum	
Snare Drum	1	Each	Drum	
Snare Drum Case	1	Each	Drum	
12" Tom	1	Each	Drum	
12" Tom Case	1	Each	Drum	
14" Tom	1	Each	Drum	
14" Tom Case	1	Each	Drum	
16" Tom	1	Each	Drum	
16" Tom Case	1	Each	Drum	
Boom stand w/Tom Mount	1	Each	Drum	
Boom stand w/boom arm and Cowbell Mount	1	Each	Drum	
Hi-hat stand w/ boom Arm and Stick Holder	1	Each	Drum	
Ride Cymbal	1	Each	Drum	
16" Crash Cymbal	1	Each	Drum	
18" Crash Cymbal	1	Each	Drum	
14" top Hi-hat	1	Each	Drum	
14" bottom Hi-hat	1	Each	Drum	
10" Splash	1	Each	Drum	
Floor Tom legs	2	Set of 3	Drum	
Snare Stand	2	Each	Drum	
Bass Drum	1	each	Drum	
Spare Strings	2	Set	Bass	
Amp Head	1	Each	Bass	
Lower Cabinet Speaker	2	Each	Bass	
Upper Cabinet Speaker	2	Each	Bass	
Bass	2	Each	Bass	
Pedal Board	1	Each	Bass	

Figure 29: Checklist for large items.

Misc Drum Case Checklist				
Name	**QTY**	**Each/Set**	**Category**	**Initials**
Drum Mics	2	Each	Drum	
14" Timbale Drum	1	Each	Drum	
Tom Legs	2	Set of 3	Drum	
Cowbell	1	Each	Drum	
Bass Drum Pedal	1	Each	Drum	
Extension Cable	1	Each	Drum	

Figure 30: Checklist for miscellaneous drum case items.

Install Design

Before building the portable storage unit, a list of tools and a bill of materials (see Figure 31 below) were created in order to map out the process. Then, the tools and materials were gathered and the building process commenced.

Tooling required:

- Drill
- Phillips Drill Bit
- Table Saw
- Router
- ½" Router Bit
- Router Clamp
- Tape Measurer
- Pencil
- Scratch Paper
- Sandpaper
- Retractable Utility

Description: Portable Storage Unit
Part Number: 12PSU34

Part Number	Description	Quantity
H-100	Base (1/2" plywood)	1
F-1175850	1" Wood Screws	22
H-317000	Wood Pegs	4
F-266355	Foam	5
F-0609287	Spray Paint	
H-200	Small Sides (3/4" plywood)	2
F-11102038	Corner Braces	2
H-C934053	Handles	2
F-1175850	1/4" Wood Screws	12
F-0609287	Spray Paint	
H-225	Inserts (1/2" plywood)	4
F-0609287	Spray Paint	
H-250	Large Sides (3/4" plywood)	2
F-11102038	Corner Braces	2
H-1403-2	Bottom Clasp	1
F-1175850	1/4" Wood Screws	10
F-0609287	Spray Paint	
H-300	Top (1/2" plywood)	1
F-11101919	Spring Hinges	2
F-11102236	Lid Support Left	1
F-11102237	Lid Support Right	1
H-1403-1	Top Clasp	1
F-1175850	1/4" Wood Screws	20
F-0609287	Spray Paint	

Figure 31: BOM for the product.

As can be seen in Figure 32, plywood boards were cut to the correct dimensions and the slots for the two large sides were made using a router.

Figure 32: Creating slots for adjustable interior walls.

Next, all pieces were painted with 3 coats of black spray paint and the logo was painted on using a cardboard stencil and orange spray paint. This can be seen in Figures 33 and 34.

Figure 33: Wood set to dry after applying paint.

Figure 34: Using a stencil to paint Louder Space's logo.

Finally, the boards were glued and screwed together and the hardware was installed. This process can be seen in Figure 35 with the resulting product as can be seen in Figure 36.

Figure 35: Pre-drilling holes before screwing the boards together.

Figure 36: Final product.

Methods

While constructing time studies of the current process, several cycles were observed and documented before any times could be recorded. Since multiple band members performed varying tasks simultaneously it was determined that the best way to break the tasks down would be to take time studies of each member individually. This method provided detailed results but did not include as much variability in the process.

In order to obtain realistic data from the time studies, the normal times were multiplied by allowances that would be included in the case that they were taken in the setting of a venue and averaged by the allowances which applied to the actual setting where the time studies were taken. Please note that poor lighting that would be found in a venue results in a 2% allowance, but averaged with a 0% allowance from the lighting in the band's practice room resulted in a 1% allowance. The allowances were broken down as so:

- Constant: 9%
- Standing: 2%
- Bending: 2%
- Lifting: 9%
- Bad Lighting: 1%
- **Total**: 23%

Reducing the amount of time required to load the gear started by targeting the non-value added tasks identified in the current process Pareto chart. The new process was designed not only to minimize the walking distance but also to greatly reduce foot traffic generated by multiple members carrying heavy equipment to the same location at the same time. One method executed in order to minimize walking distance can be seen in Fig 37. By stacking the drum cases inside of each other, a single member could carry all of the drum cases in one trip.

Figure 37: Before and after method for stacking the drum cases.

A commonly occurring non-value added task was the act of disassembling an item and then placing it on the floor, which would ultimately lead to having to pick the item up once again to load it. The new design avoided this by retrieving cases before the disassembly of the gear.

To minimize foot traffic, the new process was designed to reduce the number of paths that overlap. Previously members were tasked with carrying an item to the truck, climbing into the truck bed, and then loading the gear in. The revised process was designed so that members would take turns staying in the truck bed and

loading gear into the truck as it comes. An example of this concept can be seen in Figure 38. The idea was that having one less member walking back and forth would reduce congestion. Furthermore, having one member stay in the truck bed for multiple cycles would reduce the number of times each member had to climb into the truck bed, and as a result, reduce the time required to place gear inside the truck.

Figure 38: Before and after method for loading in gear.

Once the wasteful steps were minimized as much as possible, time studies were broken down into specific tasks that each member would then be trained on. Balancing the workloads as evenly as possible across all members, the design was tested. After careful observation, the time studies were revised in order to better balance the workloads. Recognizing the disassembly of the drums as a bottleneck in the process, Chris was tasked with aiding Philip to speed up the process. Previously, each member avoided dealing with each other's gear as a sort of accountability method. That way, each member was responsible for his own gear. However, with

the implementation of checklists, members were able to handle each other's gear without confusion.

Checklists that pertained to a case of miscellaneous items such as the portable storage unit were attached directly to that case. The master checklist was attached to the truck at the entrance to the truck bed. Each time a member loaded an item into a miscellaneous case or into the truck bed, they were tasked with checking the item off with their initials.

With the design fully implemented, post-implementation time studies were performed to gauge the effectiveness of the design in reducing the time required to load the gear. The post-implementation time studies can be seen in Appendix D, Figures 42-45. A paired t-test was performed resulting in a p-value of zero and can be seen in Fig 39. The null hypothesis was rejected indicating a significant difference in the mean loading time before and after the implementation of the new process.

$$H_0: \mu_{Before} = \mu_{After}$$
$$H_1: \mu_{Before} \neq \mu_{After}$$

Paired T-Test and CI: Before, After

```
Paired T for Before - After

            N    Mean  StDev  SE Mean
Before      6  1098.6   43.3     17.7
After       6   602.4   11.8      4.8
Difference  6  496.15   49.7     20.3


95% CI for mean difference: (444.0, 548.3)
T-Test of mean difference = 0 (vs not = 0): T-Value = 24.47  P-Value = 0.000
```

Figure 39: Paired T-Test for pre-implementation times and post-implementation times.

While the non-value added but necessary times remained about the same, significant reductions were found in walking time, inspection time, delay time and even value added time. This can be seen in table 40 based off of the post-implementation flow process charts in Appendix E, Figures 46-49.

	Before	**After**	**Difference**
Walking Distance (ft.)	319.72	247.53	72.19
Walking Time (sec)	225.08	110.95	114.13
Inspection Time (sec)	147.89	7.31	140.58
Delay Time (sec)	267.82	14.26	253.56
Total NVA Time (sec)	651.31	213.76	437.55
Total VA Time (sec)	210.07	106.84	103.23

Table 40: Before and after comparison.

While the walking distance was reduced, the difference in walking time can largely be attributed to the reduction in foot traffic. Inspection time was eliminated altogether except for a quick glance over the checklists. Delay time was greatly minimized by balancing the workloads, and therefore, minimizing wait-times. Even

value-added times were reduced through the implementation of trading off staying in the truck bed and loading in items as they arrive.

Since gear gets lost and damaged over large periods of times, the duration of this project did not allow for testing of the portable storage unit's effectiveness of protecting miscellaneous items. Instead, it was assumed that the unit, along with the checklist would guarantee 100% retention of the gear in good condition. In reality, some gear may still be subject to being misplaced or damaged due to user error.

Results and Discussion

The implementation of the new design reduced the loading process by about 45%. As can be seen in Table 41, 496.15 seconds, or just over 8 minutes was saved using the new design. The process also contained far less variation as can be seen in the reduction of the standard deviation.

	Standard Loading Time (Seconds)	Standard Deviation (Seconds)
Before	1098.55	43.3
After	602.4	11.8
Difference	496.15	49.7

Table 41: High level time comparisons

Cost savings were determined using calculations as well as several assumptions:

- Replacing Gear: ≈ $270/yr (assuming 100% retention rate of gear in good condition)
- Time Reduction: ≈ $2,150/yr (assuming a $150/hr labor rate for the band)
- Other Savings: ≈ $150/yr (i.e. gas money, excess inventory, crowd pleasure, reputation)
- **Total Savings**: ≈ $2,750/yr

The manufacturing cost of the portable storage unit was calculated with the understanding that the cost would be far cheaper per unit if it were to be mass-produced. Building just one unit accumulated high set up times and leftover

materials. Although the storage unit cost more to make (including labor costs) than to purchase a similar case from *Road Cases USA*, it is important to note that in reality there were only material costs for this project. This made manufacturing the product cheaper than buying an existing product. However, the cost analysis below was executed assuming that the labor was paid.

- Material Cost: ≈ $250
- Labor Cost: ≈ $440 (assuming a labor rate of $20/hr)
- **Total Cost**: ≈ $690 ≈ $85/yr (estimating the life expectancy to be 8 years)

The net profit was then calculated:

- ≈ $2,570/yr - $85/yr ≈ **$2,485/yr**

In order to ensure that the weight of the unit is within the acceptable lifting capacity, the lifting index (LI) was calculated using the NIOSH lifting equation. The recommended weight limit (RWL) is shown in the calculation below:

RWL = LC * HM * VM * DM * AM * FM *CM

= 51 * (10/12.5) * (1-0.0075|40-30|) * (0.82 + 1.8/32) * (1-0.0032*0) * 1.00 *1.00

= **33.1 lbs**

Where:

		METRIC	U.S. CUSTOMARY
Load Constant	LC	23 kg	51 lb
Horizontal Multiplier	HM	(25/H)	(10/H)
Vertical Multiplier	VM	1-(.003 |V-75|)	1-(.0075 |V-30|)
Distance Multiplier	DM	.82 + (4.5/D)	.82 + (1.8/D)
Asymmetric Multiplier	AM	1-(.0032A)	1-(.0032A)
Frequency Multiplier	FM	From Table 5	From Table 5
Coupling Multiplier	CM	From Table 7	From Table 7

Table 5
Frequency Multiplier Table (FM)

Frequency Lifts/min (F) ‡	Work Duration					
	≤ 1 Hour		>1 but ≤ 2 Hours		>2 but ≤ 8 Hours	
	V < 30†	V ≥ 30	V < 30	V ≥ 30	V < 30	V ≥ 30
≤0.2	1.00	1.00	.95	.95	.85	.85
0.5	.97	.97	.92	.92	.81	.81
1	.94	.94	.88	.88	.75	.75
2	.91	.91	.84	.84	.65	.65
3	.88	.88	.79	.79	.55	.55
4	.84	.84	.72	.72	.45	.45
5	.80	.80	.60	.60	.35	.35
6	.75	.75	.50	.50	.27	.27
7	.70	.70	.42	.42	.22	.22
8	.60	.60	.35	.35	.18	.18
9	.52	.52	.30	.30	.00	.15
10	.45	.45	.26	.26	.00	.13
11	.41	.41	.00	.23	.00	.00
12	.37	.37	.00	.21	.00	.00
13	.00	.34	.00	.00	.00	.00
14	.00	.31	.00	.00	.00	.00
15	.00	.28	.00	.00	.00	.00
>15	.00	.00	.00	.00	.00	.00

Table 7
Coupling Multiplier

Coupling Type	Coupling Multiplier	
	V< 30 inches (75 cm)	V ≥ 30 inches (75 cm)
Good	1.00	1.00
Fair	0.95	1.00
Poor	0.90	0.90

The LI was then determined by the ratio of the load lifted to the RWL. The maximum weight of the unit, with all possible gear inside, is 37.5 lbs. When compared to 31.8 lbs the LI is 1.13. It is said that an LI > 1 poses an increased risk for some workers

and an LI > 3 poses high risk of developing low-back pain and injury. Although the unit's LI is greater than 1, it is only slightly so. Therefore, it was deemed acceptable for this application since it will not be transported multiple times every day and the lifting can be split between the four members. The band members were made aware of the slight risk, however, and were advised to split the lifting load between two members at a time if the transportation amount increases greatly.

Conclusion

The purpose of this project was to improve Louder Space's method of transporting band equipment. Currently the band's existing problems include:

- Poor organization of equipment
- Little to no member accountability of items
- Waste in time while transporting gear
- Loss of money due to damaged or lost equipment

The following solutions were proposed, implemented, and then tested:

- Develop a consistent and standardized transportation process where each item has its own place
- Create a master checklist in order to improve member accountability
- Split the tasks evenly between members to reduce time wasted
- Save money by protecting equipment method

All objectives were accomplished but the biggest improvement that came from implementing the solutions above was the savings in time. After performing, band members are usually tired and don't have much energy left for packing up equipment. Without a standardized process there is a lot of time wasted waiting and repacking. By applying the new method of equipment organization with tasks split evenly, the transportation time was reduced to almost half. Based on these results, work-study is a very important factor to consider when an application involves

transportation. Many music artists play multiple shows per day and it is important to have a consistent, time-saving methods of transporting equipment in order to earn money.

This project was a great way to apply a multitude of learned Industrial Engineering skills to a real-world situation. Much experience was gained from starting with an idea of a problem and then creating a solution to help solve it. The project was successful, so other bands are recommended to implement similar methods to what was used for this specific band with use of the customizable, portable storage unit as well. If this project were to be continued in the future, time studies of unloading (not just loading) would be another analysis to complete. Loading/unloading time studies from a venue (not just where the band practices) would be important to consider as well. Lastly, an investigation of mass-producing the customizable unit would be an imperative factor to study.

Throughout the design of this project there were a significant amount of social and environmental impacts. The main intended social influences include the rewards that other band would receive from using the customizable storage unit, as well as an increase in fan pleasure from this band being less tardy and having more time to work on new music and perform back-to-back shows. Some unintended impacts consist of potentially supporting unfair labor practices through little in-depth research of the purchased products for building the unit, and aggravation of avid ecosystem protectors through not using completely environmentally friendly

products. These unintended environmental bearings include logging of rainforests for wood, air pollution and greenhouse gas emissions from spray paint, use of natural resources, and plywood scrap waste. However, the intended effects are comprised of the fact that less hazardous electrical equipment will be thrown away, the five-in-one compact design which reduces use of materials, the reuse of the checklists due to lamination, and the fact that the unit is designed to be long lasting from its sealant and supports. Overall the benefits of both social and environmental impacts were deemed to outweigh the negatives, so the project was considered to be valid.

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Appendices

Appendix A: Current Process Time Studies

Operation: Loading gear
Observer: Kyle
Operator: Philip (Drums)

	Element Description		Cycles						Summary Data			
			1	2	3	4	5	6	SUM	AVG	R	N
1	Remove microphone from stand	R										
		T	2.42	3.71	2.17	1.68	3.86	4.01	17.85	2.38	1	2.38
2	Walk to counter	R										
		T	3.81	14.53	12.58	10.31	8.87	11.83	68.53	11.42	1	11.42
3	Place microphone on counter	R										
		T	0.83	2.01	2.69	1.06	1.43	3.51	11.53	1.92	1	1.92
4	Walk to drum kit	R										
		T	5.36	9.61	8.93	17.24	8.01	6.85	56	9.33	1	9.33
5	Collapse mic stand and place on floor	R										
		T	21.84	27.42	24.25	19.38	16.9	18.72	128.51	21.42	1	21.42
6	Walk to hi-hat/cymbal case	R										
		T	64.15	73.8	66.38	88.49	79.53	77.48	449.83	74.97	1	74.97
7	Pick up case	R										
		T	6.23	2.16	5.77	7.41	4.06	5.95	31.58	5.26	1	5.26
8	Walk back to drum kit	R										
		T	14.78	9.64	8.76	8.2	11.57	7.37	60.32	10.05	1	10.05
9	Remove hi-hats and cymbals	R										
		T	103.5	122.4	101.3	111.3	118.2	129.8	686.6	114.43	1	114.43
10	Place in case	R										
		T	31.58	42.05	40.73	49.04	37.51	46.81	247.72	41.29	1	41.29
11	Remove Rack Tom from stand	R										
		T	24.07	21.14	17.42	22.56	19.46	19.07	123.72	20.62	1	20.62
12	Place on floor	R										
		T	4.73	2.47	4.51	2.83	1.99	3.73	20.26	3.38	1	3.38
13	Collapse hi-hat/cymbal stands	R										
		T	55.71	44.21	50.08	51.87	48.96	63.29	314.12	52.35	1	52.35
14	Place on floor	R										
		T	1.34	0.92	1.8	3.52	2.37	2.11	12.06	2.01	1	2.01
15	Remove legs from Floor Toms and Place Toms on f	R										
		T	92.57	99.65	101.3	87.65	81.83	89.31	552.88	92.15	1	92.15
16	Remove snare from stand	R										
		T	13.2	18.28	16.2	14.38	15.14	18.83	96.03	16.01	1	16.01
17	Place on floor	R										
		T	2.86	1.92	3.45	2.5	4.26	1.99	16.98	2.83	1	2.83
18	Collapse snare stand	R										
		T	18.63	14.13	25.29	15.79	20.44	22.3	116.58	19.43	1	19.43
19	Place on floor	R										
		T	1.12	2.48	3.16	2.33	2.98	3.03	15.1	2.52	1	2.52
20	Unclamp bass pedal from bass	R										
		T	14.69	12.05	16.93	9.62	11.84	13.87	79	13.17	1	13.17
21	Place on floor	R										
		T	2.75	1.91	1.87	4.67	3.12	1.58	15.9	2.65	1	2.65
22	Walk to drum cases	R										
		T	8.53	11.83	9.34	10.72	7.58	12.21	60.81	10.14	1	10.14
23	Pick up about half of drum cases	R										
		T	15.77	12.69	8.75	11.73	14.38	13.02	76.34	12.82	1	12.82
24	Walk back to drums	R										
		T	13.36	9.14	11.24	10.32	11.06	13.28	74.4	12.40	1	12.40
25	Load drums into individual bags	R										
		T	86.4	69.87	71.89	79.41	94.7	73.83	476.1	79.35	1	79.35
26	Walk to remaining drum cases	R										
		T	11.24	10.85	12.09	13.22	9.8	11.81	69.01	11.50	1	11.50
27	Pick up remaining drum cases	R										
		T	4.51	7.87	6.9	14.82	9.39	5.12	48.61	8.10	1	8.10
28	Walk back to drums	R										
		T	10.62	12.22	8.91	9.76	11.63	12.56	65.7	10.95	1	10.95
29	Load remaining drums into individual bags	R										
		T	53.09	67.66	65.82	51.65	60.59	61.05	359.86	59.98	1	59.98
30	Inspect that all gear has been loaded	R										
		T	137.9	183.2	147	174.6	193.9	168.8	1006.3	167.71	1	167.71

* Observed Time = Avgerage Time
* Time in seconds

Total ST = 1038.55

Figure 5: Current-state time study taken of Philip (drums) during the loading process of the gear.

Operation:	Loading gear											
Observer:	Marissa											
Operator:	Clayton (Guitar)											
Element Description			Cycles						Summary Data			
			1	**2**	**3**	**4**	**5**	**6**	**SUM**	**AVG**	**R**	**N**
1	Unplug guitar	R										
		T	0.09	1.35	1.09	2.41	0.91	0.84	6.69	1.11	1	1.115
2	Walk to case	R										
		T	3.34	5.11	3.14	7.53	5.12	3.94	28.2	4.70	1	4.70
3	Put guitar in case	R										
		T	24.1	19.6	27.8	21.1	18.6	22.6	134	22.3	1	22.29
4	Walk to pedal board	R										
		T	2.76	4.63	4.12	3.95	3.49	3.21	22.2	3.69	1	3.69
5	Unplug pedal board	R										
		T	6.77	5.31	4.92	6.69	7.2	6.12	37	6.17	1	6.17
6	Walk to case	R										
		T	2.61	4.11	2.28	3.57	6.05	2.85	21.5	3.58	1	3.58
7	Place pedal board in case	R										
		T	22	20.2	18.8	16.6	27.9	24.3	130	21.6	1	21.62
8	Walk to amp	R										
		T	1.43	3.94	2.64	1.09	2.47	1.89	13.5	2.24	1	2.24
9	Unplug amp head	R										
		T	9.64	7.69	10.8	9.23	9.35	8.21	54.9	9.16	1	9.16
10	Unplug amp	R										
		T	7.32	6.59	11.7	8.22	10.6	7.87	52.3	8.71	1	8.71
11	Wrap cables	R										
		T	61.2	53	68.4	47.1	59.3	59.2	348	58	1	58.05
12	Walk to backpack	R										
		T	9.2	7.47	10.8	6.48	6.53	9.63	50.1	8.36	1	8.36
13	Place cables inside backpack	R										
		T	27.6	18.2	23.5	31.7	26.4	29.6	157	26.2	1	26.17
14	Walk to biggest item available	R										
		T	2.08	4.21	3.56	2.68	1.97	2.65	17.2	2.86	1	2.86
15	Pick up item	R										
		T	3.51	2.44	3.84	2.93	4.16	2.88	19.8	3.29	1	3.29
16	Carry item to truck	R										
		T	15.7	12.3	13.1	18.3	14.7	11.8	86	14.3	1	14.33
17	Place item in truck bed	R										
		T	30.1	24.7	33.8	28.7	20.5	38.6	176	29.4	1	29.39
18	Walk back to gear	R										
		T	7.88	10.3	8.45	8.63	7.39	14.2	56.9	9.49	1	9.49
19	Repeat until all available gear is loaded	R										
		T	278	258	312	354	333	284	1820	303	1	303.3
20	Inspect that all gear has been loaded	R										
		T	119	137	109	98.3	63.5	84.2	611	102	1	101.8
21	Wait for Oren to load in last of drums and Philip to	R										
		T	204	306	184	229	287	307	1517	253	1	252.8

* Observed Time = Avgerage Time
* Time in seconds

Total ST = 1099

Figure 6: Current-state time study taken of Clayton (guitar) during the loading process of the gear.

Operation:	Loading gear											
Observer:	Logan											
Operator:	Oren (Bass)											
Element Description			Cycles						Summary Data			
			1	**2**	**3**	**4**	**5**	**6**	**SUM**	**AVG**	**R**	**N**
1	Unplug bass	R										
		T	0.83	0.94	0.55	1.26	0.99	1.3	5.87	0.98	1	0.98
2	Walk to case	R										
		T	2.63	2.16	3.12	2.2	1.96	2.51	14.58	2.43	1	2.43
3	Place guitar in case	R										
		T	19.14	16.96	14.73	18.64	24.28	15.65	109.4	18.23	1	18.23
4	Walk to pedal board	R										
		T	1.93	1.74	1.57	2.94	1.55	2.71	12.44	2.07	1	2.07
5	Unplug pedal board	R										
		T	12.2	8.38	5.97	6.32	11.64	9.11	53.62	8.94	1	8.94
6	Walk to case	R										
		T	5.85	6.41	8.24	4.62	3.73	5.47	34.32	5.72	1	5.72
7	Place pedal board in case	R										
		T	17.4	13.23	14.23	12.86	23.72	19.04	100.48	16.75	1	16.75
8	Walk to amp	R										
		T	4.27	5.74	3.21	2.75	6.9	3.54	26.41	4.40	1	4.40
9	Unplug amp head	R										
		T	9.66	8.62	4.33	6.39	5.67	7.43	42.1	7.02	1	7.02
10	Unplug speakers	R										
		T	14.31	13.19	15.39	8.64	11.15	12.34	75.02	12.50	1	12.50
11	Wrap cables	R										
		T	36.61	38.61	29.74	43.86	31.77	40.62	221.21	36.87	1	36.87
12	Walk to backpack	R										
		T	1.43	2.35	1.1	2.63	1.59	3.48	12.58	2.10	1	2.10
13	Place cables in backpack	R										
		T	24.21	21.14	19.21	29.77	17.67	23.41	135.41	22.57	1	22.57
14	Fold guitar/bass rack and place on groun	R										
		T	3.86	2.82	2.18	3.91	1.98	2.4	17.15	2.86	1	2.86
15	Walk to merch box	R										
		T	14.38	13.89	11.87	10.91	17.83	12.23	81.11	13.52	1	13.52
16	Pick up merch box	R										
		T	2.7	3.56	1.84	4.35	3.21	2.94	18.6	3.10	1	3.10
17	Carry to truck	R										
		T	9.74	8.21	11.54	9.68	10.36	9.45	58.98	9.83	1	9.83
18	Place item in truck bed	R										
		T	6.53	5.96	7.38	4.5	4.87	5.35	34.59	5.77	1	5.77
19	Walk back to gear	R										
		T	5.5	7.62	6.52	14.39	4.98	8.23	47.24	7.87	1	7.87
20	Pick up biggest item available	R										
		T	2.44	1.46	1.94	3.18	2.6	1.84	13.46	2.24	1	2.24
21	Carry item to truck	R										
		T	5.82	3.42	11.86	8.29	6.12	12.73	54.24	9.04	1	9.04
22	Place item in truck bed	R										
		T	2	3.81	5.23	1.83	14.8	4.21	31.88	5.31	1	5.31
23	Walk back to gear	R										
		T	4.79	8.39	5.16	4.92	6.58	4.46	34.3	5.72	1	5.72
22	Repeat until all gear is loaded	R										
		T	237.3	279.6	223.4	300.2	256.7	248.9	1546.2	###	1	257.69
21	Inspect that all gear has been loaded	R										
		T	158.5	98.72	48.24	109.7	83.25	135.5	633.91	105.65	1	105.65
22	Wait for Philip to finish disassembling dr	R										
		T	97.63	145.6	252.5	115.5	166.2	160.1	937.48	156.25	1	156.25
23	Carry last of drums to the truck	R										
		T	7.25	4.94	6.14	7.1	8.74	5.32	39.49	6.58	1	6.58
24	Place items in truck bed	R										
		T	4.37	3.29	3.65	4.94	3.91	3.89	24.05	4.01	1	4.01
25	Wait for Philip to do inspection	R										
		T	126.2	175	137.2	162.5	181.2	160.6	942.72	157.12	1	157.12

* Observed Time = Avgerage Time
* Time in seconds

Total ST = 1098.55

Figure 7: Current-state time study taken of Oren (bass) during the loading process of the gear.

Appendix B: Current Process Flow Charts

Location: Practice Room
Activity: Packing Bass Gear
Date: January 25, 2014
Operator: Oren
Circle Appropriate Method and Type
Method: (Present) Proposed
Type: (Worker) Material Machine
Analyst: Logan

Event Description	Time (min)	Dist (ft)	Notes/Method Recommendation
Unplug bass	1.21		
Walk to case	2.99	8.83	
Place guitar in case	22.42		
Walk to pedal board	2.55	6.24	
Unplug pedal board	11.00		
Walk to case	7.04	9.91	
Place pedal board in case	20.60		
Walk to amp	5.41	11.12	
Unplug amp head	8.63		
Unplug speakers	15.38		
Wrap cables	45.35		
Walk to backpack	2.58	6.62	
Place cables in backpack	27.76		Cables become very tangle
Fold guitar/bass rack and place on groun	3.52		
Walk to merch box	16.63	42.89	
Pick up merch box	3.81		
Carry to truck	12.09	26.22	
Place item in truck bed	7.10		
Walk back to gear	9.68	18.58	
Pick up biggest item available	2.76		
Carry item to truck	11.12	18.58	
Place item in truck bed	6.53		
Walk back to gear	7.04	18.58	
Repeat until all gear is loaded	316.96	222.96	6 repeats
Inspect that all gear has been loaded	129.95		
Wait for Philip to finish disassembling dr	192.19		
Carry last of drums to the truck	8.09	18.58	
Place items in truck bed	4.93		
Wait for Philip to do inspection	193.26		
Total =	1098.6	409.11	

Figure 9: Current-state process flow chart taken of Oren (bass) during the loading process of the gear.

Location: Practice Room
Activity: Packing Guitar Gear
Date: January 25, 2014
Operator: Clayton
Circle Appropriate Method and Type
Method: (Present) Proposed
Type: (Worker) Material Machine
Analyst: Marissa

Event Description	Time (Sec)	Dist (ft)	Notes/Method Recommendation
Unplug guitar	1.37		
Walk to case	5.78	9.25	
Put guitar in case	27.42		
Walk to pedal board	4.54	5.75	
Unplug pedal board	7.59		
Walk to case	4.40	4.00	
Place pedal board in case	26.59		
Walk to amp	2.76	3.50	
Unplug amp head	11.27		
Unplug amp	10.71		
Wrap cables	71.40		
Walk to backpack	10.28	4.17	
Place cables inside backpack	32.19		Cables become very tangled
Walk to biggest item available	3.52	3.65	
Pick up item	4.047		
Carry item to truck	17.63	18.58	Often have to pause and wait for path to cle
Place item in truck bed	36.15		
Walk back to gear	11.67	18.58	Center point of room to truck bed
Repeat until all available gear is loaded	373.06	222.96	6 repeats
Inspect that all gear has been loaded	125.31		
Wait for Oren to load in last of drums and Philip to inspe	310.94		
Total =	1098.6	290.44	

Figure 10: Current-state process flow chart taken of Clayton (guitar) during the loading process of the gear.

Location: Practice Room
Activity: Packing Drum Gear
Date: January 25, 2014
Operator: Philip
Circle Appropriate Method and Type
Method: (Present) Proposed
Type: (Worker) Material Machine
Analyst: Kyle

Event Description	Time (min)	Dist (ft)	Notes/Method Recommendation
Remove microphone from stand	3.67		
Walk to counter	14.05	9.23	
Place microphone on counter	2.36		
Walk to drum kit	11.48	12.47	
Collapse mic stand and place on floor	26.35		
Walk to hi-hat/cymbal case	92.21	45.61	Opened combo lock to sh
Pick up case	6.47		
Walk back to drum kit	12.36	45.61	
Remove hi-hats and cymbals	140.7		
Place in case	50.79		
Remove Rack Tom from stand	25.36		
Place on floor	4.16		
Collapse hi-hat/cymbal stands	64.39		
Place on floor	2.47		
Remove legs from Floor Toms and Place Toms or	113.3		
Remove snare from stand	19.69		
Place on floor	3.48		
Collapse snare stand	23.9		
Place on floor	3.1		
Unclamp bass pedal from bass	16.2		
Place on floor	3.26		
Walk to drum cases	12.47	42.28	
Pick up about half of drum cases	15.77		Could be stacked efficient
Walk back to drums	15.25	42.28	
Load drums into individual bags	97.6		
Walk to remaining drum cases	14.15	42.28	
Pick up remaining drum cases	9.96		
Walk back to drums	13.47	42.28	
Load remaining drums into individual bags	73.78		
Inspect that all gear has been loaded	206.3		
Total =	1099	282.04	

Figure 11: Current-state process flow chart taken of Philip (drums) during the loading process of the gear.

Appendix C: In or Out Categorization Charts

Chris/Vox

Name	QTY	Each/Set	Category
Mic	2	Each	In
Straight Mic Stand	1	Each	Out
Bent Mic Stand	1	Each	Out
Mic to PA cables	2	Each	In
Vocal Speakers	2	Each	Out
PA	I	Each	Out
Tambourine	1	Each	In
Set Lists	4	Each	In

Figure 20: List of gear needed for vocals.

Clay/Guitar

Name	QTY	Each/Set	Category
Guitar Pick	10	Each	Both
Spare strings	2	Set	Out
Guitar	2	each	Out
Guitar Capo	1	each	In
Guitar Pedalboard	1	each	Out
Surge protector/ extension cord	1	each	In
1/4" Guitar Cables	3	each	In
Power Chord for amp	1	each	In
Vox ACH50	1	each	Out
Fender 4x12 cab	1	each	Out
Guitar strap	2	each	In
Wire cutters	1	each	In
Guitar rack	1	each	Out

Figure 21: List of gear needed for guitar.

Oren/Bass

Name	QTY	Each/Set	Category
Bass Pick	15	Each	In
Spare Strings	2	Set	Out (bass case)
Amphead	1	Each	Out
Lower cabinet Speaker	2	Each	Out
Upper cabinet Speaker	2	Each	Out
Bass	2	Each	Out
Pedalboard	1	Each	Out
Cables	5	Each	In

Figure 22: List of gear needed for bass.

Philip/Drums

Name	QTY	Each/Set	Category
Drum Sticks: ProMark 721	2	Set	In
Bass Drum Pedal	1	Each	Out (hw case)
Snare Drum	1	Each	Out
Snare Drum case	1	Each	Out
12" Tom	1	Each	Out
12" Tom case	1	Each	Out
14" Tom	1	Each	Out
14" Tom case	1	Each	Out
16" Tom	1	Each	Out
16" Tom case	1	Each	Out
Drum stool	1	Each	Out (hw case)
Boom stand w/Tom mount	1	Each	Out
Boom stand w/boom arm and Cowbell mount	1	Each	Out
Hi-hat stand w/ boom arm and stick holder	1	Each	Out
cowbell	1	Each	Out (hw case)
tambourine	1	Each	Out (hw case)
Ride Cymbal	1	Each	Out (cymbal case)
16" Crash Cymbal	1	Each	Out (cymbal case)
18" Crash Cymbal	1	Each	Out (cymbal case)
14" top hihat	1	Each	Out (cymbal case)
14" bottom hihat	1	Each	Out (cymbal case)
10" splash	1	Each	Out (cymbal case)
Floor tom legs	2	set of 3	Out (hw case)
Snare stand	2	Each	Out (hw case)
14" timbale drum	1	Each	Out (hw case)
Drum light controller/power supply	1	Each	In
Bass Drum	1	each	out
drum mics	2	Each	Out
extention cable	1	Each	Out
2 mic cables (for drum mics)	2	Each	Out

Figure 23: List of gear needed for drums.

Appendix D: Post-Implementation Time Studies

Operation:		Loading Gear											
Observer:		Kent											
Operator:	Chris	Chris (vocals)											
Element Description			Cycles						Summary Data			
			1	2	3	4	5	6	SUM	AVG	R	N
1	Walk to truck	R										
		T	4.12	5.29	5.68	6.09	4.37	4.35	29.9	4.98	1	4.98
2	Open hatch	R							0			
		T	20.65	23.52	18.79	24.38	19.95	22.4	129.69	21.62	1	21.62
4	Walk to drum cases	R							0			
		T	7.28	8.85	9.54	7.92	7.13	6.33	47.05	7.84	1	7.84
5	Pick up drum cases	R							0			
		T	4.35	5.3	6.92	4.87	4.21	6.22	31.87	5.31	1	5.31
6	Walk back to gear	R							0			
		T	5.19	6.34	4.49	5.12	5.96	5.1	32.2	5.37	1	5.37
7	Remove legs from toms	R							0			
		T	109.23	105.61	106.94	114.68	119.62	103.03	659.11	109.85	1	109.85
8	Place legs inside case. Check off item.	R							0			
		T	17.26	12.81	21.64	18.92	17.91	21.92	110.46	18.41	1	18.41
9	Carry case to truck	R							0			
		T	8.41	7.19	11.44	8.38	7.92	9.57	52.91	8.82	1	8.82
10	Place on end of truck bed. Check off item.	R							0			
		T	14.96	16.72	12.38	14.7	12.82	11.79	83.37	13.90	1	13.90
11	Walk back to gear	R							0			
		T	4.81	5.39	5.11	4.32	5.67	4.56	29.86	4.98	1	4.98
12	Pick up hi-hat/cymbal case	R							0			
		T	2.49	3.97	4.63	2.29	4.56	2.06	20	3.33	1	3.33
13	Walk back to truck	R							0			
		T	4.18	5.98	6.12	4.79	5.31	5.19	31.57	5.26	1	5.26
14	Place on end of truck bed. Check off item.	R							0			
		T	15.47	16.29	14.81	15.74	12.8	14.19	89.3	14.88	1	14.88
15	Walk back to gear	R							0			
		T	4.9	4.37	5.21	6.83	5.56	4.51	31.38	5.23	1	5.23
16	Pick up tom and place in case	R							0			
		T	15.74	19.81	16.61	21.01	18.12	15.01	106.3	17.72	1	17.72
17	Pick up case	R							0			
		T	2.18	2.23	2.53	2.41	3.42	3.06	15.83	2.64	1	2.64
18	Walk to truck	R							0			
		T	4.28	4.93	5.67	7.09	5.81	4.9	32.68	5.45	1	5.45
19	Place on end of truck bed. Check off item.	R							0			
		T	18.29	19.03	16.72	15.29	21.28	17.99	108.6	18.10	1	18.10
20	Walk back to gear	R							0			
		T	4.4	3.69	5.11	4.21	5.27	4.93	27.61	4.60	1	4.60
21	Pick up snare	R							0			
		T	1.63	2.14	4.58	2.57	3.12	2.94	16.98	2.83	1	2.83
22	Carry to truck	R							0			
		T	5.57	4.91	5.82	6.5	5.27	4.54	32.61	5.44	1	5.44
23	Place on end of truck bed. Check off item.	R							0			
		T	17.91	18.82	19.61	14.09	17.21	19.06	106.7	17.78	1	17.78
24	Walk back to gear	R							0			
		T	4.87	5.82	5.61	5.93	4.12	5.35	31.7	5.28	1	5.28
25	Pick up tom	R							0			
		T	2.21	2.83	3.94	2.07	3.35	3.87	18.27	3.05	1	3.05
26	Carry to truck	R							0			
		T	4.96	5.38	5.12	6.41	6.91	6.32	35.1	5.85	1	5.85
27	Place on end of truck bed. Check off item.	R							0			
		T	16.72	14.68	19.41	13.97	12.63	14.85	92.26	15.38	1	15.38
28	Walk back to gear	R							0			
		T	4.89	5.71	6.66	4.21	3.59	5.53	30.59	5.10	1	5.10
29	Pick up two drum stands	R							0			
		T	7.82	6.59	6.21	5.26	4.03	6.06	35.97	6.00	1	6.00
30	Carry to truck	R							0			
		T	5.96	4.87	5.04	5.28	4.42	2.29	27.86	4.64	1	4.64
31	Place in truck bed. Check off item.	R							0			
		T	22.58	24.27	21.8	19.61	23.43	19.94	131.63	21.94	1	21.94
32	Walk back to gear	R							0			
		T	4.22	4.89	6.04	4.16	5.62	4.36	29.29	4.88	1	4.88
33	Pick up two drum stands	R							0			
		T	8.73	7.29	5.71	8.92	7.75	6.65	45.05	7.51	1	7.51
34	Carry to truck	R							0			
		T	5.93	4.62	5.68	4.13	6.28	5.36	32	5.33	1	5.33
35	Place in truck bed. Check off item.	R							0			
		T	21.46	19.39	23.28	20.21	22.35	16.46	123.15	20.53	1	20.53
36	Walk back to gear	R							0			
		T	4.93	5.67	3.97	4.62	6.11	4.43	29.73	4.96	1	4.96
37	Pick up storage unit	R							0			
		T	4.11	4.86	4.29	3.85	3.24	4.08	24.43	4.07	1	4.07
38	Carry to truck	R							0			
		T	13.49	12.88	11.63	12.69	12.42	10.71	73.82	12.30	1	12.30
39	Place inside truck. Check off item.	R							0			
		T	21.68	18.31	18.64	19.43	24.18	22.73	124.97	20.83	1	20.83
40	Inspect that all items have been or are being	R							0			
		T	29.24	21.67	23.41	25.74	19.28	23.19	142.53	23.76	1	23.76
41	Wait till finish	R							0			
		T	11.04	16.05	14.98	14.27	10.86	17.02	84.22	14.04	1	14.04

* Observed Time = Avgerage Time
* Time in minutes

Total NT = 602.40

Figure 42: Post-implementation time study taken of Chris (vocals) during the loading process of the gear.

Operation:	Loading Gear											
Observer:	Marizza											
Operator:	Clayton (guitar)											
Element Description			Cycles						Summary Data			
			1	2	3	4	5	6	SUM	AVG	R	N
1	Unplug guitar	R										
		T	0.98	1.14	1.29	0.91	0.83	1.01	6.16	1.03	1	1.03
2	Walk to case	R										
		T	4.89	3.93	5.69	4.72	3.88	5.1	28.21	4.70	1	4.70
3	Place guitar in case	R										
		T	21.64	23.45	20.63	17.91	20.59	22.84	127.06	21.18	1	21.18
4	Walk back to amp	R										
		T	2.33	1.95	2.68	2.32	1.86	2.03	13.17	2.20	1	2.20
5	Unplug amp head	R										
		T	8.14	13.75	10.21	9.76	10.42	9.63	61.91	10.32	1	10.32
6	Unplug amp	R										
		T	7.73	9.29	9.96	8.12	8.86	7.98	51.94	8.66	1	8.66
7	Carry amp to truck	R										
		T	13.94	16.55	13.67	14.89	15.21	12.72	86.98	14.50	1	14.50
8	Place amp inside truckbed. Check off item.	R										
		T	54.75	51.83	53.31	51.77	51.06	48.63	311.35	51.89	1	51.89
9	Take bottom bass speakers from Oren and place in	R										
		T	24.54	19.89	19.21	22.12	20.62	23.86	130.24	21.71	1	21.71
10	Take guitar amphead from Oren and place in truckb	R										
		T	19.62	22.34	23.62	17.69	20.2	19.88	123.35	20.56	1	20.56
11	Take top bass speakers from Oren and place in truc	R										
		T	10.08	8.61	12.93	14.26	12.32	10.28	68.48	11.41	1	11.41
12	Walk back to gear	R										
		T	5.21	4.84	4.91	5.72	6.4	5.53	32.61	5.44	1	5.44
13	Pick up bass amphead	R										
		T	2.11	2.34	1.87	1.29	2.68	3.21	13.5	2.25	1	2.25
14	Carry to truck	R										
		T	9.17	7.92	9.05	7.94	7.61	8.47	50.16	8.36	1	8.36
15	Place on end of truck bed. Check off item.	R										
		T	16.58	14.2	13.02	15.96	17.85	15.31	92.92	15.49	1	15.49
16	Walk back to gear	R										
		T	5.06	4.43	4.29	5.89	5.63	4.91	30.21	5.04	1	5.04
17	Unplug pedal board	R										
		T	6.76	4.51	7.28	6.91	5.53	6.82	37.81	6.30	1	6.30
18	Carry pedal board to case	R										
		T	2.72	2.94	1.86	1.77	2.21	1.83	13.33	2.22	1	2.22
19	Place pedal board in case	R										
		T	18.24	22.83	20.64	23.46	22.63	19.92	127.72	21.29	1	21.29
20	Pick up case	R										
		T	2.14	3.41	2.94	2.35	2.18	3.12	16.14	2.69	1	2.69
21	Carry to bass pedal board	R										
		T	3.88	3.56	2.76	4.08	2.56	2.17	19.01	3.17	1	3.17
22	Pick up bass pedal board	R										
		T	4.38	5.73	7.91	3.93	6.32	5.49	33.76	5.63	1	5.63
23	Carry to truck	R										
		T	6.25	9.46	7.89	11.21	8.26	7.82	50.89	8.48	1	8.48
24	Place on end of truck bed. Check off item.	R										
		T	12.46	14.29	10.38	14.42	13.93	9.21	74.69	12.45	1	12.45
25	Climb into truck	R										
		T	2.48	2.81	3.14	1.96	1.84	2.27	14.5	2.42	1	2.42
26	Take drum cases from Chris and place in truck bed	R										
		T	56.31	49.61	44.15	51.18	57.92	49.22	308.39	51.40	1	51.40
27	Take pedal boards and place in truck bed	R										
		T	11.19	13.59	12.76	11.8	13.53	9.79	72.66	12.11	1	12.11
28	Take remaining guitar and bass and place in truck b	R										
		T	4.82	8.29	9.49	8.41	5.28	7.94	44.23	7.37	1	7.37
29	Walk back to gear	R										
		T	4.98	5.32	3.81	4.07	5.77	5.12	29.07	4.85	1	4.85
30	Pick up PA	R										
		T	2.07	3.14	1.63	2.71	2.98	1.82	14.35	2.39	1	2.39
31	Carry to truck	R										
		T	6.81	8.45	10.95	5.48	10.47	7.79	49.95	8.33	1	8.33
32	Place on end of truck bed. Check off item.	R										
		T	12.86	10.27	15.31	11.32	9.95	14.62	74.33	12.39	1	12.39
33	Walk back to gear	R										
		T	4.85	3.94	5.32	5.06	4.72	4.61	28.5	4.75	1	4.75
34	Pick up vocal speaker	R										
		T	3.45	2.18	3.47	1.95	3.71	2.29	17.05	2.84	1	2.84
35	Carry to truck	R										
		T	8.31	10.42	9.52	8.1	12.31	11.25	59.91	9.99	1	9.99
36	Place on end of truck bed. Check off item.	R										
		T	12.42	15.84	14.38	16.71	13.4	12.28	85.03	14.17	1	14.17
37	Walk back to gear	R										
		T	4.69	5.02	5.33	3.92	4.16	3.22	26.34	4.39	1	4.39
38	Unplug main mic	R										
		T	1.22	0.79	2.01	1.53	2.13	0.94	8.62	1.44	1	1.44
39	Collapse mic stand	R										
		T	16.34	19.29	22.14	18.2	24.53	18.75	119.25	19.88	1	19.88
40	Walk to backup mic	R										
		T	3.27	4.58	2.04	5.41	2.98	3.45	21.73	3.62	1	3.62
41	Unplug backup mic	R										
		T	2.65	1.94	4.57	2.53	3.97	1.84	17.5	2.92	1	2.92
42	Place both mics in storage unit. Check off items.	R										
		T	14.54	16.92	12.86	12.34	10.99	13.92	81.57	13.60	1	13.60
43	Collapse mic stand	R										
		T	19.42	14.52	15.37	18.49	16.74	13.6	98.14	16.36	1	16.36
44	Carry both mic stands to truck	R										
		T	5.62	6.18	4.98	5.48	6.42	6.11	34.79	5.80	1	5.80
45	Place in truck bed. Sign off items.	R										
		T	14.29	12.68	13.3	13.56	8.21	10.44	72.48	12.08	1	12.08
46	Wait till finish	R										
		T	11.95	0	17.24	13.35	2.21	13.81	58.56	9.76	1	9.76

* Observed Time = Avgerage Time

* Time in minutes

Total NT = 602.40

Figure 43: Post-implementation time study taken of Clayton (guitar) during the loading process of the gear.

Operation:	Loading Gear											
Observer:	Logan											
Operator:	Oren	Oren (bass)										
Element Description			Cycles						Summary Data			
			1	2	3	4	5	6	SUM	AVG	R	N
1	Unplug bass	R										
		T	0.71	0.94	0.53	1.12	0.91	0.63	4.84	0.81	1	0.81
2	Walk to guitar case	R										
		T	2.93	2.12	3.09	1.94	1.87	2.31	14.26	2.38	1	2.38
3	Place bass in case	R										
		T	22.3	18.64	21.07	19.86	20.25	17.91	120.03	20.01	1	20.01
4	Walk to amp	R										
		T	3.45	4.15	3.87	2.24	3.02	2.94	19.67	3.28	1	3.28
5	Unplug amp head	R										
		T	8.72	11.23	8.44	10.63	12.42	10.43	61.87	10.31	1	10.31
6	Unplug top speakers	R										
		T	7.24	6.31	7.01	6.83	4.82	7.67	39.88	6.65	1	6.65
7	Unplug bottom speakers	R										
		T	5.46	6.37	6.92	4.22	7.89	5.14	36	6.00	1	6.00
8	Pick up bottom bass speaker	R										
		T	3.62	2.96	3.21	3.01	2.85	2.63	18.28	3.05	1	3.05
9	Carry speaker to truck	R										
		T	8.92	7.79	10.34	8.61	7.38	7.9	50.94	8.49	1	8.49
10	Place on end of truck bed. Check off item.	R										
		T	18.78	22.19	23.09	19.41	18.24	21.25	122.96	20.49	1	20.49
11	Walk back to gear	R										
		T	.4.73	5.82	5.23	3.94	6.36	5.22	26.57	5.31	1	5.31
12	Pick up guitar amphead	R										
		T	2.31	2.73	3.06	2.89	3.14	3.7	17.83	2.97	1	2.97
13	Carry to truck	R										
		T	8.91	9.23	8.07	7.13	9.69	8.01	51.04	8.51	1	8.51
14	Place on end of truck bed. Check off item.	R										
		T	14.25	16.83	16.24	17.18	18.71	16.02	99.23	16.54	1	16.54
15	Walk back to gear	R										
		T	4.33	6.14	5.56	5.08	6.37	4.92	32.4	5.40	1	5.40
16	Pick up top bass speaker	R										
		T	2.64	3.55	2.39	2.81	2.99	3.21	17.59	2.93	1	2.93
17	Carry to truck	R										
		T	8.44	8.68	9.73	10.41	7.99	9.12	54.37	9.06	1	9.06
18	Place on end of truck bed. Check off item.	R										
		T	17.23	15.85	17.29	16.06	14.91	16.35	97.69	16.28	1	16.28
19	Walk back to gear	R										
		T	4.28	4.91	4.44	5.37	5.18	4.77	28.95	4.83	1	4.83
20	Wrap bass cables and place in portable stor	R										
		T	73.46	69.28	75.12	71.92	67.55	72.58	429.91	71.65	1	71.65
21	Walk to guitar cables	R										
		T	2.35	1.97	2.68	2.01	3.18	2.72	14.91	2.49	1	2.49
22	Wrap cables and place in portable storage u	R										
		T	79.31	76.69	71.27	78.92	73.35	69.62	449.16	74.86	1	74.86
23	Pick up vocal speaker	R										
		T	2.11	3.08	2.36	1.92	2.47	1.84	13.78	2.30	1	2.30
24	Carry to truck	R										
		T	8.28	10.12	8.94	11.23	7.41	6.83	52.81	8.80	1	8.80
25	Place on end of truck bed. Check off item.	R										
		T	14.22	12.35	17.11	14.32	12.96	15.61	86.57	14.43	1	14.43
26	Walk back to gear	R										
		T	3.31	5.62	3.58	4.62	4.07	4.41	25.61	4.27	1	4.27
27	Pick up remaining bass and guitar	R										
		T	5.27	4.39	4.82	5.15	4.63	4.21	28.47	4.75	1	4.75
28	Carry to truck	R										
		T	6.34	5.95	5.81	6.12	6.94	5.86	37.02	6.17	1	6.17
29	Place on end of truck bed. Check off item.	R										
		T	15.23	13.39	16.71	13.82	15.03	12.96	87.14	14.52	1	14.52
30	Walk back to gear	R										
		T	5.21	5.67	3.68	4.41	5.76	4.71	29.44	4.91	1	4.91
31	Pick up cymbal stand	R										
		T	3.11	2.76	3.92	2.62	2.21	2.31	16.93	4.84	1	4.84
32	Carry to truck	R										
		T	11.31	9.67	11.35	13.48	10.96	9.12	65.89	10.98	1	10.98
33	Place in truck bed. Check off item.	R										
		T	17.93	19.22	15.64	15.21	17.38	16.01	101.39	16.90	1	16.90
34	Walk back to gear	R										
		T	4.68	5.59	7.21	5.91	4.18	4.42	31.99	5.33	1	5.33
35	Pick up two drum stands	R										
		T	6.7	4.37	7.09	5.65	5.11	6.83	35.75	5.96	1	5.96
36	Carry to truck	R										
		T	5.94	5.14	4.85	4.34	5.16	6.21	31.64	5.27	1	5.27
37	Place in truck bed. Check off item.	R										
		T	18.46	16.29	15.73	17.13	14.55	12.32	94.48	15.75	1	13.33
38	Walk back to gear	R										
		T	4.28	4.79	5.18	5.75	3.31	5.79	29.1	4.85	1	4.85
39	Pick up guitar rack	R										
		T	1.31	1.92	1.78	1.64	0.98	1.55	9.18	1.53	1	1.53
40	Carry to truck	R										
		T	5.32	6.47	4.91	4.48	5.17	5.13	31.48	5.25	1	5.25
41	Place in truck bed. Check off item.	R										
		T	14.13	15.68	13.29	19.41	14.08	16.72	93.31	15.55	1	15.55
42	Walk to merch box	R										
		T	8.13	5.73	7.84	7.92	6.14	6.35	42.11	7.02	1	7.02
43	Pick up merch box	R										
		T	1.74	2.32	1.38	0.97	1.21	1.63	9.25	1.54	1	1.54
44	Carry to truck	R										
		T	7.18	9.12	10.63	9.67	8.14	9.53	54.27	9.05	1	9.05
45	Place in front cab of truck. Check off item.	R										
		T	18.31	14.29	19.31	15.6	16.39	17.45	101.35	16.89	1	16.89
46	Wait till finish	R										
		T	0	0.66	0	0	17.65	0	18.31	3.05	1	3.05

* Observed Time = Avgerage Time

* Time in minutes

Total ST = 602.40

Figure 44: Post-implementation time study taken of Oren (bass) during the loading process of the gear.

Operation:	Loading Gear											
Observer:	Kyle											
Operator:	Philip (drums)											
Element Description			Cycles						Summary Data			
			1	2	3	4	5	6	SUM	AVG	R	N
1	Remove hi-hats and cymbals	R										
		T	131.61	124.23	120.36	126.52	132.4	129.25	764.37	127.40	1	127.40
2	Place in case	R										
		T	43.69	38.27	45.21	40.86	37.21	36.24	241.48	40.25	1	40.25
3	Remove snare from stand	R										
		T	19.62	20.41	19.74	22.61	16.43	22.01	120.82	20.14	1	20.14
4	Place in case	R										
		T	9.56	12.1	14.57	11.61	16.12	11.79	75.75	12.63	1	12.63
5	Remove tom from stand	R										
		T	19.23	21.39	17.34	22.93	20.45	18.96	120.3	20.05	1	20.05
6	Place tom on floor	R										
		T	2.64	1.92	3.03	2.27	2.19	3.46	15.51	2.59	1	2.59
7	Unclamp bass pedal from bass	R										
		T	8.91	11.43	7.62	13.41	9.85	10.31	61.53	10.26	1	10.26
8	Place in portable storage unit. Check	R										
		T	9.71	12.81	9.39	8.68	8.12	9.74	58.45	9.74	1	9.74
9	Place bass drum in case	R										
		T	21.42	19.33	25.51	22.49	18.67	19.2	126.62	21.10	1	21.10
10	Pick up case	R										
		T	3	2.53	2.12	4.84	7.91	3.41	23.81	3.97	1	3.97
11	Carry to truck bed (18.56)	R										
		T	9.26	7.63	11.41	7.25	8.31	8.94	52.8	8.80	1	8.80
12	Place on end of truck bed. Check off it	R										
		T	14.62	18.89	16.38	13.49	22.94	15.63	101.95	16.99	1	16.99
13	Walk back to gear	R										
		T	5.68	4.12	4.08	3.61	4.67	5.24	27.4	4.57	1	4.57
14	Place last remaining tom in case	R										
		T	16.72	13.45	21.26	17.55	15.06	17.68	101.72	16.95	1	16.95
15	Pick up case	R										
		T	3.19	3.25	3.91	1.95	2.62	3.06	17.98	3.00	1	3.00
16	Carry to truck bed	R										
		T	7.28	9.8	7.54	6.84	8.91	6.42	46.79	7.80	1	7.80
17	Place on end of truck bed. Check off it	R										
		T	15.23	12.39	18.49	14.09	17.41	16.17	93.78	15.63	1	15.63
18	Walk back to gear	R										
		T	4.38	5.12	5.86	4.91	3.27	4.61	28.15	4.69	1	4.69
19	Collapse hi-hat/cymbal stands and pl	R										
		T	52.1	49.54	53.18	50.44	47.87	41.66	294.79	49.13	1	49.13
20	Collapse snare stand	R										
		T	18.26	16.52	19.29	19.28	17.61	15.58	106.54	17.76	1	17.76
21	Carry to truck	R										
		T	5.13	4.79	8.82	4.46	7.95	6.22	37.37	6.23	1	6.23
22	Place inside truck bed. Check off item.	R										
		T	16.72	13.26	14.33	17.91	18.62	15.11	95.95	15.99	1	15.99
23	Walk back to gear	R										
		T	6.71	6.56	4.21	4.36	3.72	5.31	30.87	5.15	1	5.15
24	Pick up PA stands	R										
		T	8.62	6.28	9.37	7.12	5.29	6.81	43.49	7.25	1	7.25
25	Carry to truck bed	R										
		T	7.21	9.18	8.41	7.63	6.81	9.33	48.57	8.10	1	8.10
26	Place in truck bed. Check off item.	R										
		T	14.92	17.28	14.48	16.29	10.92	13.42	87.31	14.55	1	14.55
27	Wait till finish	R										
		T	12.72	26.25	15.86	19.56	22.53	17.29	114.21	19.04	1	19.04

* Observed Time = Avgerage Time
* Time in minutes

Total NT = 602.4

Figure 45: Post-implementation time study taken of Philip (drums) during the loading process of the gear.

Appendix E: Post-Implementation Flow Process Charts

Location:	Practice Room
Activity:	Loading Gear
Date:	Saturday, February 22, 2014
Operator:	Chris
Circle Appropriate Method and Type	
Method:	Present Proposed
Type:	Worker Material Machine
Analyst:	Kent

Event Description	Time (min)	Dist (ft)	Notes/Method Recommendation
Walk to truck	6.13	18.58	
Open hatch	26.59		
Walk to drum cases	9.64	26.16	
Pick up drum cases	6.53		
Walk back to gear	6.61	42.89	
Remove legs from toms	135.12		
Place legs inside case. Check off item.	22.64		
Carry case to truck	10.85	18.58	
Place on end of truck bed. Check off iten	17.10		
Walk back to gear	6.13	18.58	
Pick up hi-hat/cymbal case	4.10		
Walk back to truck	6.47	18.58	
Place on end of truck bed. Check off iten	18.30		
Walk back to gear	6.43	18.58	
Pick up tom and place in case	21.80		
Pick up case	3.25		
Walk to truck	6.70	18.58	
Place on end of truck bed. Check off iten	22.26		
Walk back to gear	5.66	18.58	
Pick up snare	3.48		
Carry to truck	6.69	18.58	
Place on end of truck bed. Check off iten	21.87		
Walk back to gear	6.49	18.58	
Pick up tom	3.75		
Carry to truck	7.20	18.58	
Place on end of truck bed. Check off iten	18.92		
Walk back to gear	6.49	18.58	
Pick up tom	3.75		
Carry to truck	7.20	18.58	
Place on end of truck bed. Check off iten	18.92		
Walk back to gear	6.27	18.58	
Pick up two drum stands	7.38		
Carry to truck	5.71	18.58	
Place in truck bed. Check off item.	26.99		
Walk back to gear	6.00	18.58	
Pick up two drum stands	9.24		
Carry to truck	6.56	18.58	
Place in truck bed. Check off item.	25.25		
Walk back to gear	6.10	18.58	
Pick up storage unit	5.01		
Carry to truck	15.13	18.58	
Place inside truck. Ckeck off item.	25.62		
Inspect that all items have been or are be	29.22		
Wait till finish	17.27		
Total =	602.4	366.33	

Figure 46: Post-implementation flow process chart taken of Chris (vocals) during the loading process of the gear.

Location:	Practice Room
Activity:	Loading Gear
Date:	Saturday, February 22, 2014
Operator:	Clayton
Circle Appropriate Method and Type	
Method:	(Present) Proposed
Type:	(Worker) Material Machine
Analyst:	Marissa

Event Description	Time (min)	Dist (ft)	Notes/Method Recommendation
Unplug guitar	1.27		
Walk to case	5.78	9.25	
Place guitar in case	26.05		
Walk back to amp	2.71	5.75	
Unplug amp head	12.69		
Unplug amp	10.65		
Carry amp to truck	17.84	18.58	
Place amp inside truckbed. Check off item.	63.82		
Take bottom bass speakers from Oren and place i	26.70		
Take guitar amphead from Oren and place in truck	25.29		
Take top bass speakers from Oren and place in tr	14.03		
Walk back to gear	6.69	18.58	
Pick up bass amphead	2.77		
Carry to truck	10.28	18.58	
Place on end of truck bed. Check off item.	19.05		
Walk back to gear	6.20	18.58	
Unplug pedal board	7.75		
Carry pedal board to case	2.73	5.25	
Place pedal board in case	26.19		
Pick up case	3.31		
Carry to bass pedal board	3.90	7.33	
Pick up bass pedal board	6.92		
Carry to truck	10.43	18.58	
Place on end of truck bed. Check off item.	15.31		
Climb into truck	2.98		
Take drum cases from Chris and place in truck bed	63.22		
Take pedal boards and place in truck bed	14.90		
Take remaining guitar and bass and place in truck	9.07		
Walk back to gear	5.97	18.58	
Pick up PA	2.94		
Carry to truck	10.25	18.58	
Place on end of truck bed. Check off item.	15.24		
Walk back to gear	5.84	18.58	
Pick up vocal speaker	3.49		
Carry to truck	12.29	18.58	
Place on end of truck bed. Check off item.	17.43		
Walk back to gear	5.40	18.58	
Unplug main mic	1.77		
Collapse mic stand	24.45		
Walk to backup mic	4.45	10.83	
Unplug mic	3.59		
Place both mics in storage unit. Check off items.	16.73		
Collapse mic stand	20.00		
Carry both mic stands to truck	7.13	18.58	
Place in truck bed. Sign off items.	14.86		
Wait till finish	12.00		
Total =	602.4	242.79	

Figure 47: Post-implementation flow process chart taken of Clayton (guitar) during the loading process of the gear.

Location:	Practice Room							
Activity:	Loading Gear							
Date:	Saturday, February 22, 2014							
Operator:	Oren							
Circle Appropriate Method and Type								
Method:	(Present)	Proposed						
Type:	(Worker)	Material	Machine					
Analyst:	Logan							
Event Description						Time (min)	Dist (ft)	Notes/Method Recommendation
Unplug bass	●	⇨	D	□	▽	1.00		
Walk to guitar case	○	➡	D	□	▽	2.93	8.83	
Place bass in case	●	⇨	D	□	▽	24.61		
Walk to amp	○	➡	D	□	▽	4.03	10.25	
Unplug amp head	●	⇨	D	□	▽	12.68		
Unplug top speakers	●	⇨	D	□	▽	8.18		
Unplug bottom speakers	●	⇨	D	□	▽	7.38		
Pick up bottom bass speaker	●	⇨	D	□	▽	3.75		
Carry speaker to truck	○	➡	D	□	▽	10.44	18.58	
Place on end of truck bed. Check off item.	●	⇨	D	□	▽	25.20		
Walk back to gear	○	➡	D	□	▽	6.53	18.58	
Pick up guitar amphead	●	⇨	D	□	▽	3.65		
Carry to truck	○	➡	D	□	▽	10.47	18.58	
Place on end of truck bed. Check off item.	●	⇨	D	□	▽	20.34		
Walk back to gear	○	➡	D	□	▽	6.64	18.58	
Pick up top bass speaker	●	⇨	D	□	▽	3.60		
Carry to truck	○	➡	D	□	▽	11.14	18.58	
Place on end of truck bed. Check off item.	●	⇨	D	□	▽	20.02		
Walk back to gear	○	➡	D	□	▽	5.94	18.58	
Wrap bass cables and place in portable storage	●	⇨	D	□	▽	88.13		
Walk to guitar cables	○	➡	D	□	▽	3.06	8.83	
Wrap cables and place in portable storage unit.	●	⇨	D	□	▽	92.08		
Pick up vocal speaker	●	⇨	D	□	▽	2.83		
Carry to truck	○	➡	D	□	▽	10.82	18.58	
Place on end of truck bed. Check off item.	●	⇨	D	□	▽	17.75		
Walk back to gear	○	➡	D	□	▽	5.25	18.58	
Pick up remaining bass and guitar	●	⇨	D	□	▽	5.84		
Carry to truck	○	➡	D	□	▽	7.59	18.58	
Place on end of truck bed. Check off item.	●	⇨	D	□	▽	17.86		
Walk back to gear	○	➡	D	□	▽	6.04	18.58	
Pick up cymbal stand	●	⇨	D	□	▽	5.95		
Carry to truck	○	➡	D	□	▽	13.51	18.58	
Place in truck bed. Check off item.	●	⇨	D	□	▽	20.79		
Walk back to gear	○	➡	D	□	▽	6.56	18.58	
Pick up two drum stands	●	⇨	D	□	▽	7.33		
Carry to truck	○	➡	D	□	▽	6.48	18.58	
Place in truck bed. Check off item.	●	⇨	D	□	▽	19.37		
Walk back to gear	○	➡	D	□	▽	5.97	18.58	
Pick up guitar rack	●	⇨	D	□	▽	1.88		
Carry to truck	○	➡	D	□	▽	6.46	18.58	
Place in truck bed. Check off item.	●	⇨	D	□	▽	19.13		
Walk to merch box	○	➡	D	□	▽	8.63	26.16	
Pick up merch box	●	⇨	D	□	▽	1.89		
Carry to truck	○	➡	D	□	▽	11.13	26.16	
Place in front cab of truck. Check off item.	●	⇨	D	□	▽	20.77		
Wait till finish	○	⇨	●	□	▽	0.73		
					Total =	602.4	358.93	

Figure 48: Post-implementation flow process chart taken of Oren (bass) during the loading process of the gear.

Location:	Practice Room							
Activity:	Loading Gear							
Date:	Saturday, February 22, 2014							
Operator:	Philip							
Circle Appropriate Method and Type								
Method:	Present	Proposed						
Type:	Worker	Material	Machine					
Analyst:	Kyle							
Event Description						**Time (min)**	**Dist (ft)**	**Notes/Method Recommendation**
Remove hi-hats and cymbals	●	⇨	D	□	▽	156.70		
Place in case	●	⇨	D	□	▽	49.51		
Remove snare from stand	●	⇨	D	□	▽	24.77		
Place in case	●	⇨	D	□	▽	15.53		
Remove tom from stand	●	⇨	D	□	▽	24.66		
Place on floor	●	⇨	D	□	▽	3.19		
Unclamp bass pedal from bass	●	⇨	D	□	▽	12.62		
Place in storage unit. Check off item.	●	⇨	D	□	▽	11.98		
Place bass drum in case	●	⇨	D	□	▽	26.08		
Pick up case	●	⇨	D	□	▽	4.88		
Carry to truck bed (18.56)	○	➡	D	□	▽	10.82	18.58	
Place on end of truck bed. Check off item.	●	⇨	D	□	▽	20.90		
Walk back to gear	○	➡	D	□	▽	5.62	18.58	
Place last remaining tom in case	●	⇨	D	□	▽	20.85		
Pick up case	●	⇨	D	□	▽	3.69		
Carry to truck bed (18.56)	○	➡	D	□	▽	9.59	18.58	
Place on end of truck bed. Check off item.	●	⇨	D	□	▽	19.22		
Walk back to gear	○	➡	D	□	▽	5.77	18.58	
Collapse hi-hat/cymbal stands and place c	●	⇨	D	□	▽	60.43		
Collapse snare stand	●	⇨	D	□	▽	21.84		
Carry to truck	○	➡	D	□	▽	7.66	18.58	
Place inside truck bed. Check off item.	●	⇨	D	□	▽	19.67		
Walk back to gear	○	➡	D	□	▽	6.33	18.58	
Pick up PA stands	●	⇨	D	□	▽	8.92		
Carry to truck	○	➡	D	□	▽	9.96	18.58	
Place in truck bed. Check off item.	●	⇨	D	□	▽	17.90		
Wait till finish	○	⇨	●	□	▽	23.32		
					Total =	602.4	130.06	

Figure 49: Post-implementation flow process chart taken of Philip (drums) during the loading process of the gear.