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Implementation of Lean Principles at the University of Michigan Orthotics and Prosthetics Center Based on the Implementation Method Outlined in Lean Thinking

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Implementation of Lean Principles at the University of Michigan Orthotics and Prosthetics Center Based on the Implementation Method Outlined in *Lean Thinking*

By

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Abstract

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The Problem Situation

It is August 2006 and Anita Liberman-Lampear, the Director at UMOPC is struggling with organizational and operational problems. Anita realizes that UMOPC has reached the peak capacity for its production environment. Over the last 15 years the facility's patient base, revenue, and workforce have all tripled in size, and more growth is on the way due to an aging society, more survivors from traumatic accidents and a greater number of people suffering from diabetes. The facility has already added onto its clinical space, but it is in need of more space in the fabrication lab. The fabrication lab is crowded with technicians, equipment, and general clutter. In addition to the shrinking size of the lab, the technicians are also frustrated with their work environment and the lack of standardized production methods. There is also tension between the practitioners and technicians. Often the practitioners do not fill out their order forms carefully enough, and in most cases the technicians have to take the practitioners aside to have them define their specifications and objectives. The production time varies greatly between each technician and it seems that in the scheduling of work certain technicians are being favored over others. Furthermore, the exam rooms are out of date and ergonomically unsatisfactory for both patients and employees. Every area of the facility (waiting rooms,

production lab, exam rooms etc.) can barely handle the volume of patients. Something needs to be done (Liberman-Lampear,12 Dec 2006).

Increasing the size of the facility can solve the capacity problem but not the problems in the production lab. If the problems are not solved in the lab, they will carry over to the improved facility and will slow down the whole operation. Anita has already presented her plan to the proper authorities of the University of Michigan Hospital and it looks like she might be able to get the funding and space to add on to the facility. She is hesitant though and she wants to make sure that the old problems will not be translated to a larger facility. Anita is looking for some method to address the problems with the processes in the production lab, and increase communication between the technicians, practitioners, and the whole Orthotics and Prosthetics team.

Anita's final approval for the addition does not need to be given right away, but the number of patients UMOPC is seeing continues to rise and their capacity is being stretched to the limit. Anita needs to find a relatively quick method, to accommodate the needs of UMOPC's patients (Liberman-Lampear,12 Dec 2006).

The Orthotics and Prosthetics Organization at the University of Michigan

To better understand the situation Anita is facing at UMOPC, the organization's mission, products and staff and some history are described in this section.

Mission and Products

The University of Michigan Orthotics and Prosthetics Center is an organization designed to provide its patients with an improved quality of life at the best possible quality care at lowest possible costs through their products. The complete mission statement can be found at their website: http://www.med.umich.edu/pmr/op/aboutus.htm.

The devices produced by UMOPC can be broken down into two product types: orthoses and prostheses. While UMOPC provides other products, called off-the-shelf custom fit, they only fabricate orthoses and prostheses. Appendix A contains an example of an orthosis, and appendix B contains an example of a prosthesis.

Orthoses are devices which support, correct or assist the movement of a specific body part or section of the body. They are commonly made from plastics and bound together with metal joints and Velcro straps. At UMOPC, three product families make up Orthotics. These families are:

- Upper Extremity Orthoses (abbreviated UEO, consists of devices which correct, assist, and support movements of the arms, elbows, wrists and/or hands)
- Lower Extremity Orthoses (abbreviated LEO, consists of devices which correct, assist, and support movements of the legs, ankles and/or feet)
- Spine Orthoses (consists of devices which correct, assist, and support movements of the spine, neck and/or head).

For each product family there is a large number of different part configurations which can make up any one orthotic.

Prostheses are devices fabricated to replace a patient's limbs and/or extremities. They are made by first creating a prosthetic socket (where the prosthetic interfaces with the patient). Sockets made primarily with two materials, plastic and carbon fiber. They are then filled with a softer plastic and a lining for comfort. A steel pylon is then attached to the bottom of the socket to create a structure, a knee is added if requested, and a terminal device is added at the end of the pylon (foot, hand, etc.). Depending on the

patient's desire the device can be made to look like a normal limb or the socket and pylon may be left uncovered.

Prostheses are produced for the following body parts: hands, arms, legs, knees, breasts and feet. Prosthetics can be made with any combination of special parts, such as computers, bioelectrical response sensors, and other hi-tech componentry.

The UMOPC Team

To measure, fit, and produce prostheses and orthoses, a large team of individuals are needed, including: prosthetists, orthetists, fitters or assistants, (often referred to collectively as *practitioners* in this paper), technicians and administrative staff.

Prosthetists, Orthotists, Pedorthists, Fitters, or Assistants are the team members responsible for meeting with patients, taking measurements, and deciding which devices will best support their needs. These practitioners also fit the devices to patients, and instruct patients on how to use them. Also practitioners are engaged in the research and development function of UMOPC, furthering research into the products they design for their patients. Currently, to be a practitioner one needs a bachelor's degree, clinical experience and to pass oral and written board exams (Liberman-Lampear,12 Dec 2006).

Technicians are trained in prosthetics, orthotics, or both. These team members are responsible for producing custom made prostheses and/or orthoses according to practitioner's specifications and designs. Technicians at UMOPC work either five eight hour days a week, or four ten hour days a week. Additionally, each day a different technician is on call for their shift.

Technicians need a high school diploma and certification in the area in which they work (either prosthetics, orthotics or both). Technicians are also very involved in the

research and development process as they aid practitioners in the design of new products, or create new products themselves (Liberman-Lampear,12 Dec 2006).

The **Administrative Staff** has a wide role in the organization. Members of this group manage the business aspect of the Orthotics and Prosthetics (abbreviated, O&P) operations. They also: make appointments, receive prescriptions, contact patients, handle contact with insurance companies, and create and assess the business goals and needs of the O&P organization (Liberman-Lampear,12 Dec 2006).

A History of the UMOPC Organization

This section describes a brief history of UMOPC. For a more complete history of UMOPC, please see appendix C.

UMOPC in the 1990's

After UMOPC was established in its current location on South Industrial Rd in Ann Arbor, MI in the early 1990's there was a large management change in the University Hospital. The new management questioned whether the Prosthetics and Orthotics organization should be outsourced, which was the trend of other hospitals at the time. At this time, UMOPC was losing money for the University Hospital. In 1993 Anita Liberman-Lampear was asked to take the helm at UMOPC to rescue the unit. After extensive cost cutting efforts and efficiency improvements, the facility was moved off the chopping block.

Present Day

The volume of incoming orders at UMOPC continues to grow, and the growing pains are felt the most in the production lab. Space is dwindling and processes are spread out, causing the technicians to have to move relatively large distances and bend in awkward

ways. Furthermore, the current layout is not very open, and some of the critical work centers are located in separate rooms in the production lab making for a disjointed work flow. Also, no work or production standards exist to guide the technicians in their production methods. Consequently, the methods used by technicians have grown apart over time, resulting in varying production times and qualities. All these variations, coupled with a lack of space cause friction amongst the technicians leading to low morale.

Anita Liberman-Lampear is forced to find solutions. She begins to look into expanding the floor space of the production lab to release the pressure the technicians are feeling. Anita is aware, though, that an increase in production space may not necessarily solve the problems of inefficiency and low morale. During the summer of 2006 she believes that the solution lies in embracing lean principles.

The Lean Concept

The goal of this section is to introduce the reader to lean and lean implementation so that the reader can better understand UMOPC's decision to go lean and evaluate UMOPC's progression into lean.

Lean Defined

In their watershed book on lean, Lean Thinking, authors James Womack and Daniel Jones refer to lean as being a method to specify value, line up value-crating actions in the best sequence and conduct these activities without interruption as requested by the customer while becoming progressively more efficient. Simply put, the goal of lean is to do more with less while moving the product closer to exactly what customers want. (Womack and Jones 15).

Waste Defined

Muda, which is the Japanese word for waste, is “any human activity which absorbs resources but creates no value for the end customer” (Womack and Jones 15). Some examples of muda include: mistakes requiring rework, production of items without orders, unnecessary processing steps or movement of employees or material, waiting for materials, and any good or service which does not meet the needs of the customer (Womack and Jones 15).

Womack and Jones differentiate between three types of muda.

Type One Muda are actions which create no value but are currently required by the product development, order filling, or production systems, and cannot be eliminated without a change in processes. This kind of muda cannot be removed immediately (38).

Type Two Muda are actions which do not create value as defined by the customer and can be eliminated immediately (38)

Type Three Muda are actions in a process which are redundant and can be removed immediately (48).

Mass Production

Based on the above, one can see that the currently accepted production method - mass production - produces a great amount of waste. Mass production calls for the production of a large volume of goods without orders, using large machines with large queues and wait times, pushing large amounts of finished goods towards their end customers. Change in a firm which utilizes mass production is slow because production schedules are created months before the product is produced, and any down time is shunned because standard-cost accounting states that a machine must be operating for as long as possible to get the best cost out of it leading to massive amounts of over-production - yet

more muda. Lean is the answer to mass production. To change a production environment from mass production to lean requires an understanding of the five core concepts of lean.

The Five Core Concepts

To accomplish lean implementation, a lean thinking firm has to understand five core concepts: value, the value stream, flow, pull, and perfection.

The first concept, *value*, can only be defined by the ultimate customer and it is only meaningful when expressed as a product, service or combination of both when the customer wants it at a specific price. From the customer's standpoint value creation is the only reason for the producer to exist (Womack and Jones 16). Since value creation is the only reason a customer will purchase a firm's products, a firm must focus on its customers. Without customers, a firm cannot exist. Thus, to satisfy customers, and to continue to do business, a firm must focus on its customers and define value from their view point. A customer does not care about the fancy production methods a firm utilizes if it does not give the customer what they need when they need it (Womack and Jones 17).

A reliable method for seeking out value is the creation of a dedicated product team. This team is set up for each product family and is made up of members from all functional areas of the organization, including: marketing, accounting, sales, production scheduling, engineering/research and development, and production staff. These members each have a different stake in a product and can uniquely see how value is created for a product. To understand where value comes from, the product team should talk to key customers to understand how they define value (Womack and Jones 31-32). Furthermore,

the product team is used to map the value stream and drive change through the production process (Womack and Jones 55).

The second core lean concept is identifying the *value stream*. The value stream is the set of specific actions which bring a specific product through the following steps: engineering design, production launch, order-taking, detailed scheduling, raw material transformation, and delivery (Womack and Jones 19).

To truly complete this step, the firm must draw out the entire value stream for each product (or product family). This process is called value stream mapping. To do this two different value stream maps need to be drawn. First a current state map needs to be drafted which defines each process which transfer's raw materials into finished goods, including the accompanying information flows. After mapping the current state, non value adding processes or flows need to be identified. Then a future state map should be drawn for the process. This value stream map contains the changes which will improve the value creation process and eliminate steps which are waste. What differentiates a value stream map from any other process map is that under each process box, another box needs to be drafted containing information such as: who does the operation, process operating time, process wait time, and first time quality. This helps the drafter identify and eliminate the troubled processes which hurt flow (L'abbe Wu, IV-10 – 14).

Flow is the third core concept of lean. Once a value stream is identified flow can be determined. Flow is the movement of a physical product and its associated information, through the value creating steps which transform it into the final product. To truly be lean, firms must seek continuous flow. Continuous flow is achieved when a product can be moved from raw materials to finished product without stopping.

Unfortunately, most firms today do not operate with this mentality. They produce large batches which flow into long queues. Also, many firms are organized into departments which focus on their own operations rather than on the product (Womack and Jones 22 - 23).

The fourth core concept of lean is *pull*. The theory of pull is always contrasted with the theory of push. If a firm pushes a product into the market, it is producing products which it hopes customers will buy; there usually are not any orders for these products. This can lead to a build up of finished goods inventory which may spoil or grow obsolete, among other things, if demand for the products is not there. Pull is instituted when a customer can pull a product through a company's value transforming process. In other words, pull means that the producer does not produce a product until it receives an order from its customers. (Womack and Jones 24 – 25).

While waiting to receive an order to produce a product may seem impossible, there is a method which helps firms accomplish pull, it is called takt time. "Takt time is how often you should produce one part or product, based on the rate of sales, to meet customer requirements. Takt time is calculated by dividing the customer demand rate per day (in units), into your available working time per day (in seconds)" (Rother and Shook 44). Producing to takt time will eventually require smaller, more frequent deliveries of raw materials and faster more frequent deliveries of finished goods.

The fifth and final lean core concept is *perfection*. After value, the value stream, flow and pull are all identified and implemented a firm is still not finished in its lean transformation. Fixing each of the preceding four core concepts is not an end in itself and it must be done time and time again. The needs of customers change, thus value

definition changes. If value definition changes, the rest of the core concepts must be re-planned as well. Even if value does not change, pull may change and then flow must change. If flow needs to increase more waste may be identified in the process and removed. Value, the value stream, flow and pull all go hand in hand. Often changes in one will result in changes in another. Furthermore, perfection can never truly be attained, but it can be approached. Seeking to find perfection may seem futile, but it is something that will act as a motivator, and target, for performance.

Lean and Healthcare

Implementing lean in a healthcare system is a special case, and it should be noted that there are special enablers and disablers. One enabler to note is that in the healthcare system a service is not rendered until a patient makes an appointment. This is contrasted with a large mass production firm which goods to stock, waiting for a customer's order. Thus, healthcare systems have already implemented a form of pull system.

One important lean disabler is the current structure of healthcare, which often requires a patient to see many different specialists, located in different offices on different days with very specific equipment. This process is littered with wasted time and effort on the part of the patient and healthcare system. Unfortunately, it is the way that most healthcare systems operate and this needs to be overcome for a healthcare system to become lean.

One last disabler is third party payers which include insurance companies and government programs which can drastically slow down the healthcare process. Even if a healthcare system can implement a strong lean program the insurance processing function can put a large bottleneck in the process. What makes this even more difficult is that

these processes are located outside the health system and while the health system may influence the third party payers, it cannot make them work faster. Something will need to be done with these third party payers to take a large bottleneck out of the healthcare system.

Implementing Lean

There are eight steps that are used to implement lean, these steps are: find a change agent, get the knowledge, find or create a crisis, forget grand strategy for the moment, map the value streams, begin as soon as possible, demand immediate results, and, as soon as momentum is built up, expand scope (Womack and Jones 247–255). These steps, while seemingly complex, are relatively simple.

The first step in lean implementation is to find a change agent. This is a specific member of a firm or an outsider who will drive the lean transformation process. The change agent must be forceful and push the lean transformation with all their might, as well as take personal responsibility for the transformation's outcome. While being forceful, the change agent must be sensitive to the needs of people and create a positive atmosphere where ideas can be voiced, and ensure people are not run over (Womack and Jones 97-98).

After the change agent is identified, the firm must gather lean knowledge. This can be accomplished through lean literature (many trustworthy sources are listed in Lean Thinking's bibliography or through the Lean Enterprise Institute's website, http://www.lean.org/Library/Index.cfm), or from a lean customer or supplier. Another method of gaining knowledge is to hire someone who has had experience with lean implementation. Yet another method is to hire a consultant, but one must be weary of

consultants who promise too much, or who are not linked to the roots of lean, or consultants whose lean education does not come from experience in the field. In addition, the consultant's lean education should focus on implementing lean throughout the organization, not just in specific areas (Womack and Jones 248-250).

With the appropriate knowledge in place, one must find a reason to implement lean by finding or creating a crisis. To really begin full blast, there needs to be a strong reason to implement lean and a good way to do this is through a crisis. A change agent should look for a subunit of the organization and apply lean techniques full force. The change agent should also look for current internal crises through which lean techniques can be utilized and proved. To create a crisis, a change agent can look to a lean customer or supplier. Lean channel members will act as a catalyst, requiring the firm to become lean because they are and have specific needs (ex. low lot size, delivery every day of each type of product). Another way to create a crisis is to price products lower to create a need to streamline the production process, but such a route is very risky (Womack and Jones 250-251).

After a crisis has been identified, a firm should forget their grand strategy for a moment and focus on eliminating waste. Strategies (such as selling off troubled business segments or merging with competitors to achieve economies of scale) are not a bad thing, but they may just be a band-aid for a bigger problem. It is best for a firm to look inside itself and try to eliminate waste, as opposed to blaming the outside environment. (Womack and Jones 251-252).

After the firm has a focus on eliminating waste, the value stream for a product or product family must be mapped. To do this, a current state value stream map needs to be

created. From there waste needs to be identified and a future state map should be drafted with specific changes added. The future state map should be achievable, and accompanied by a one page implementation plan detailing the steps which make the future state possible (Rother and Shook 9).

Once the value streams have been mapped the next step is to begin implementation as soon as possible. This step is also linked with the next step which is demanding immediate results. To do this best a visibly poor process such as a physical material flow on the shop floor should be changed immediately to prove the power of lean to the other parts of the firm. Showing results and showing them quickly and dramatically will create a psychological sense of flow and help the firm realize its potential with lean (Womack and Jones 253-254).

The final step in the lean implementation process is to expand the scope of the implementation once momentum has been built up. After the initial implementation of lean in the previous step, it is time to expand the implementation. Since the firm can now see the effects of lean, lean can be implemented in the office and other processes where the flow of materials is more difficult to see. Once lean has been implemented on the shop floor, it should be implemented into the ordering system due to the unique demands lean has upon raw materials (more shipments more often). From there lean implementation should move out from processes which are directly affected by the changes made on the shop floor. Lean transformation efforts should continue on throughout the organization and into supplier's and customer's organizations (Womack and Jones 254-255).

Utilizing these steps, many firms ranging in size, products, country of origin, and age have implemented lean and have seen great success.

University of Michigan Orthotics and Prosthetics Center: Implementation of Lean

This section outlines how UMOPC is implementing lean based on the implementation plan laid out in the previous section. The following instances are derived from the author's own observations of UMOPC and its lean implementation.

The Change Agent

As is stated in "The Problem Situation", Anita stands at a crossroad. The facility is reaching its maximum capacity, employee morale is low, the production methods are not standardized, and communication between practitioners and technicians is poor. Anita wants to do something. During the summer of 2006 she reads Lean Thinking by Womack and Jones. Upon finishing the book Anita knows that she wants to implement lean at UMOPC. Thus, Anita becomes the change agent.

Getting the Knowledge

Upon deciding to implement lean, Anita approaches her superior with her decision. To her surprise, Anita finds out that her superior is already taking classes in lean. She then vocalizes her desire to participate in these classes and she begins taking classes in lean in December of 2006.

Also, in December 2006 Anita asks for the knowledge of Eastern Michigan University professor, Dr. Nesa L'abbe Wu and student Dana Lembrick. Professor Wu has a history of lean experience, and Dana has some idea of what lean is, but wants an actual hands-on experience in its implementation. Professor Wu suggests that Dana work with Anita to give insight and clarification as she is going through the lean

implementation process. In addition, Dana will write a paper, detailing UMOPC's progress towards lean.

To educate all members of the facility on "lean thinking", Anita sets up a facility wide meeting of the UMOPC which is held on January 29th, 2007. A one hour teach is given and the meaning and history of lean manufacturing is explained. It is also explained that UMOPC will be moving forward with lean no matter what and will implement it completely, not just partly. This meeting also gives rise to a new mantra for the facility, "No BTTWWADI (But That's The Way We've Always Done It)". UMOPC's stance was clear, lean is here to stay and there is no looking back.

During this meeting, lean teams are announced. Each team will take on a product family (UEO, Spine, Prosthetics, and LEO) and be responsible for its lean transformation. The teams are made up of members from each of the functional areas of UMOPC; Administrative Staff, Practitioners, and Technicians. The team members volunteered for their positions. For each team a team leader, a technician, is designated to lead the team's efforts. Each team has 4 members.

On March 15th 2007, Anita enlists the help of John Shook. Mr. Shook was involved with Toyota and their lean implementation in the United States for many years. Due to this experience, he has a strong understanding of the use and implementation of lean. During his March 15th visit, Mr. Shook observes the physical flow of materials in the production lab. Upon doing so, he critiques the current state map in order to help the organization better focus on its value stream mapping procedures.

Find a crisis

The crisis that puts the lean implementation into motion is easy to identify: the production facility is reaching its maximum capacity; in addition employee morale is low; and production methods are not standardized. Furthermore, a needed increase in capacity can not occur until a change in production methods occurs. Because capacity needs to be increased quickly to support the number of orders UMOPC is receiving, something must be done quickly to accommodate the increase in demand.

Forget Grand Strategy for the Moment

Even though adding a new facility to increase capacity is perceived to be the prescribed method to solve UMOPC's problems, this action is momentarily placed on the back burner. UMOPC will first be implementing lean to see if a move is truly necessary or simply a cover-up for a larger problem (Liberman-Lampear, March 29th).

To facilitate lean, new goals are instituted at UMOPC to support the lean transformation. These new goals will measure performance and progress on lean implementation plans generated by the lean teams. Also, new performance review goals are added to accommodate lean objectives. One example of these new goals, lays in the implementation of 5S (Liberman-Lampear, March 29th).

5S stands for Sort, Set in Order, Shine, Standardize and Sustain. To execute the first "S", *sort*, one must go through items in a workspace and separate needed items from unneeded items. The unneeded items are then eliminated from the workspace, freeing up room. The next "S", *set in order*, is what is done with the items which are left over after sorting. These items are to be placed in designated areas or spaces which should be labeled clearly for everyone to see. After setting items in a workspace in order, the next "S" states that these items should be *shined*. Shine simply means that the tools and

workspace itself should be clean of dirt, dust or other debris. Shining up a workspace leads to the fourth "S", *standardization*. To standardize the 5S process, procedures need to be enacted to sort and straighten a workspace in a timely and standard fashion. Finally, the 5S process needs to be *sustained*. To sustain 5S requires labels and other visual controls which remind employees to keep the right items in the right places. It also requires periodic review (L'abbe Wu, VI-14).

To implement 5S UMOPC takes a picture of each employee's workspace before 5S implementation. Then, randomly over the year, pictures are taken of the workspace to see if the employee has been keeping their workspace clean and organized, in a standard fashion. A workspace managed by 5S is part of every UMOPC employee's biannual performance review.

Map the Value Streams

In the beginning of the month of March, 2007 the lean teams start to map the current state of the O&P process. The team leader from each team first defines what is in and out of scope for the value stream (see appendix D for picture). Next, the team leader designs a SIPOC or Suppliers, Inputs, Outputs, Customers diagram. This diagram defines who/what the Suppliers, Inputs, Outputs, and Customers are for each product family excluding items on the "Out" of scope list, and including the items from the "In" scope list (see appendix E for picture).

Later during the month of March 2007, each team meets for the first time and is educated further as to what lean is, its goals, and how they are achieved. They then map the value stream for the most common product of their product family (see appendix F). Each group's value stream map begins with the doctor's prescription and ends with the

product being delivered/fitted to the patient. Under each process box of the value stream map, another box is drawn which defines the person who does the process; the process time (hands-on work/machining time); the wait time (time a product sits and waits for parts of the process to be carried out); and the percent of time a quality product is produced the first time. Some groups choose to explode the fabrication process out and draw up a separate value stream map for fabrication due to the amount of steps involved in the fabrication of a product.

Finally, during a large meeting on March 29th, each team spends a day to work on a future state value stream map for their product family (see appendix G). Here each team is allowed to plan their own future state with minimal input from the people who are detached from the processes. After constructing their future state maps, the teams creates an implementation plan, defining the major deliverables of a specific process change, tasks necessary to make the deliverables possible, group member responsible for carrying out the tasks, the resources the tasks need, and the time table for carrying out each task.

Begin as Soon as Possible

When the implementation plans are created, they are created with time in mind. The plans must begin within one week of the March 29th meeting.

Demand Immediate Results

The evaluation plans will be reviewed every 30, 60 and 90 days, the first 30 day meeting will be held on May 8th. Furthermore, each of the process changes as defined by the deliverables section of the implementation plan must have the potential to be implemented immediately. Also, the process changes must be in visible areas where a

change can be noticed and where the initial process was particularly poor, as defined by the current state map.

As Soon as Momentum is Built Up, Expand Scope

UMOPC is still working up its momentum so it can expand the scope of its lean implementation. The first evaluation plan reviews will begin on May 8th, 2007.

As these first changes are implemented each group will be responsible for defining more changes to implement as well as new current state maps. These items will be discussed during the 30, 60 and 90 day evaluation meetings.

Evaluation of Lean Implementation at UMOPC and Suggestions

Currently seven of the eight steps of the lean implementation cycle have been carried out at UMOPC. Anita Liberman-Lampear continues to be the change agent and will be evaluating the lean groups implementation plans, current and future state maps.

The results of lean implementation are being seen at UMOPC. One such example is the institution of a pull system for fabrication scheduling. Rather than have a team leader assign work to each technician, the technicians pick up the orders themselves. Each work order is logged on a piece of paper by the practitioner as it is placed in the fabrication area, and as each technician has time they select the next job, as determined by the paper log, and fabricate it. This change alone is causing a large jump in employee morale. The technicians feel empowered and the work is being fabricated more efficiently than ever. This very visible and exciting change has caused an increased interest in the implementation of lean manufacturing and also a better understanding of flow.

As the lean effort continues to expand, it is suggested that UMOPC continues to focus its efforts on flow. By instituting a better flow, UMOPC will realize the benefits of lean and build up momentum and understanding. To better understand flow, it is suggested that when drafting current state maps the process group members follow the actual physical work flows through the organization. This will help give the staff an understanding of what really goes on with the work flows, not simply what they think happens.

As the momentum builds, UMOPC should turn its efforts to standardizing and documenting its processes. Standardizing processes will also improve communications between technicians, practitioners and the administrative staff.

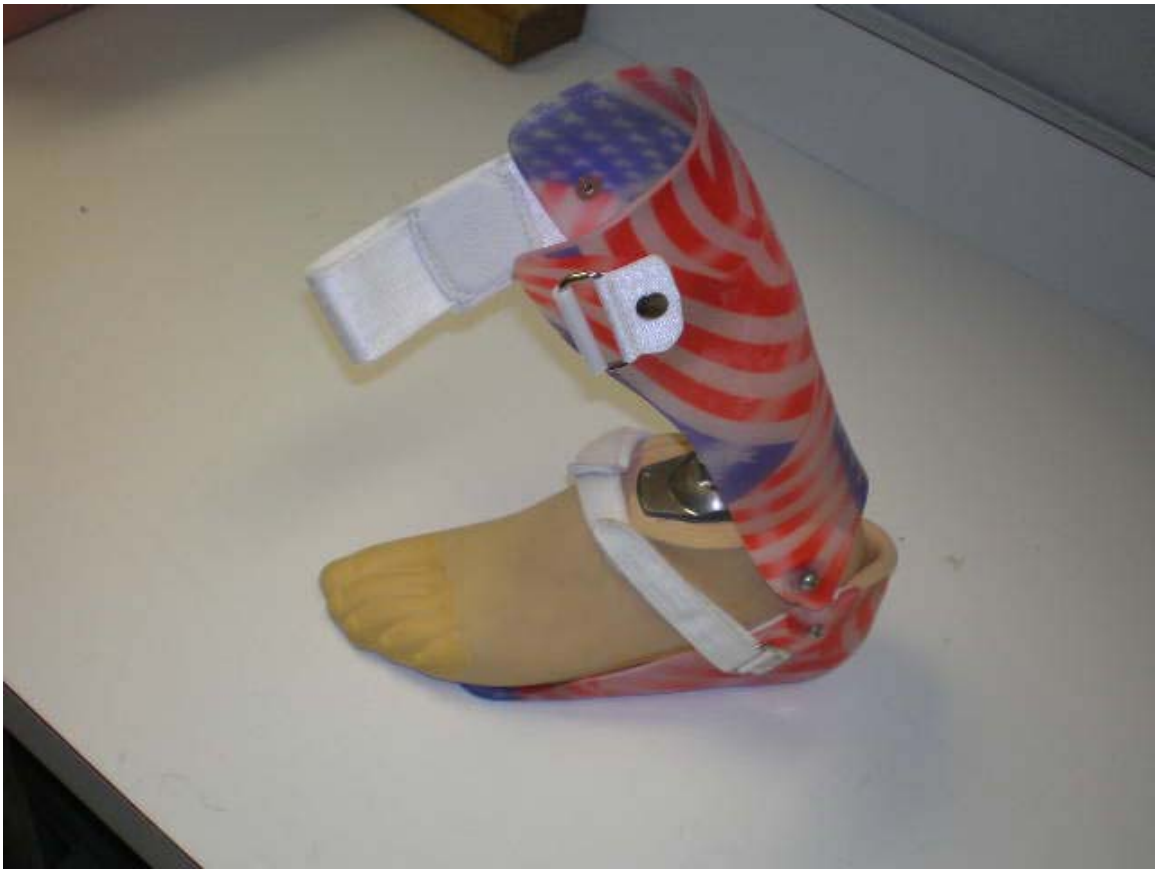
While the teams continue to report on their implementation plans, UMOPC as an organization needs to redefine its goals and objectives as they align with lean. Key lean measures should be assigned and assessed as defined by what customers deem important. These measures can include: lead time targets, overall first time quality ratings, and customer satisfaction. By instituting goals and objectives which align with lean, UMOPC can insure that it continues to grow in the right direction.

Conclusions

UMOPC's lean implementation efforts are currently matching up with the implementation plan laid out in Lean Thinking. As the firm continues to move through the final step of implementation, it is suggested that the firm keeps flow in mind as the next wave of implementations begins. Also, work standards, and new goals and standards need to be expressed to better lead future lean efforts. If UMOPC continues to

follow these suggestions, and gathers input on how they are doing, the lean transformation will be a success.

Appendix A



An example of a Lower Extremity Orthosis (LEO) with an articulating ankle.

Appendix B

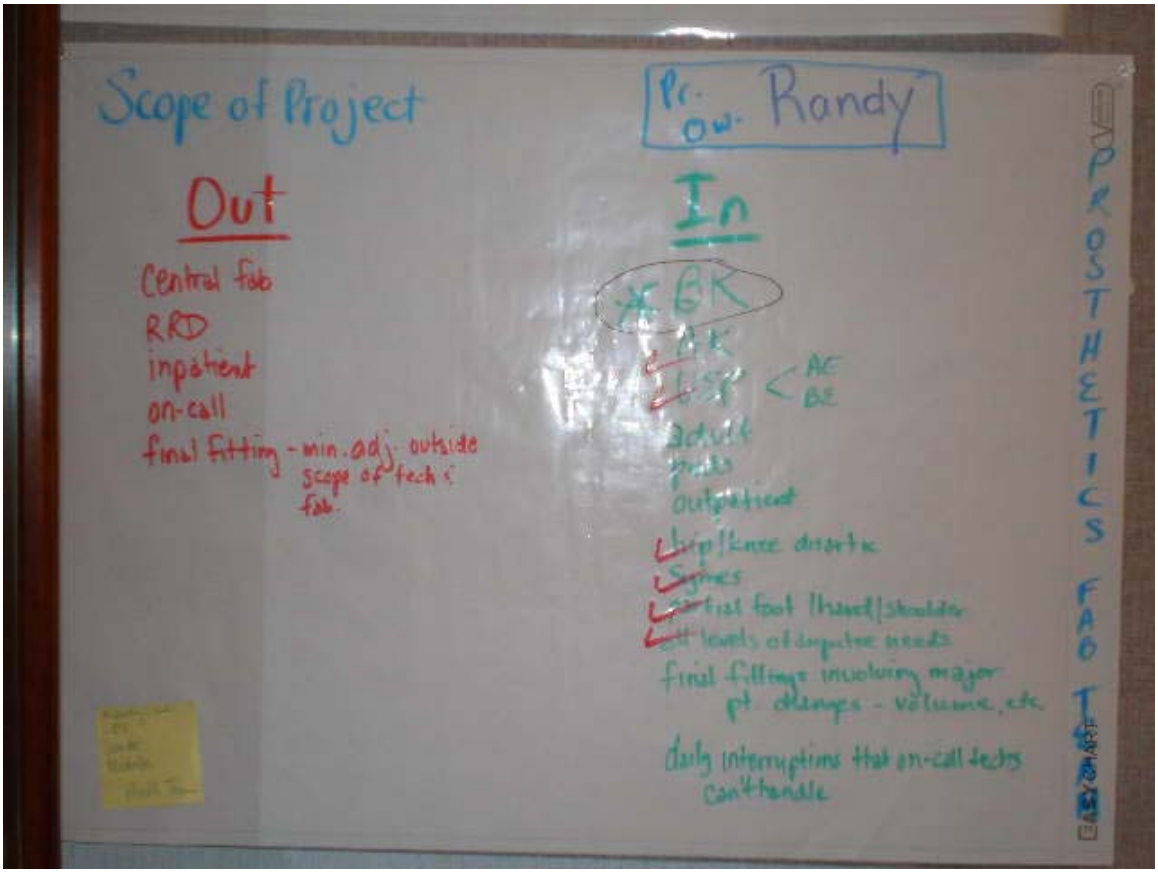
An example of a Below Knee (BK) prosthesis.

Appendix C

The Development of UMOPC

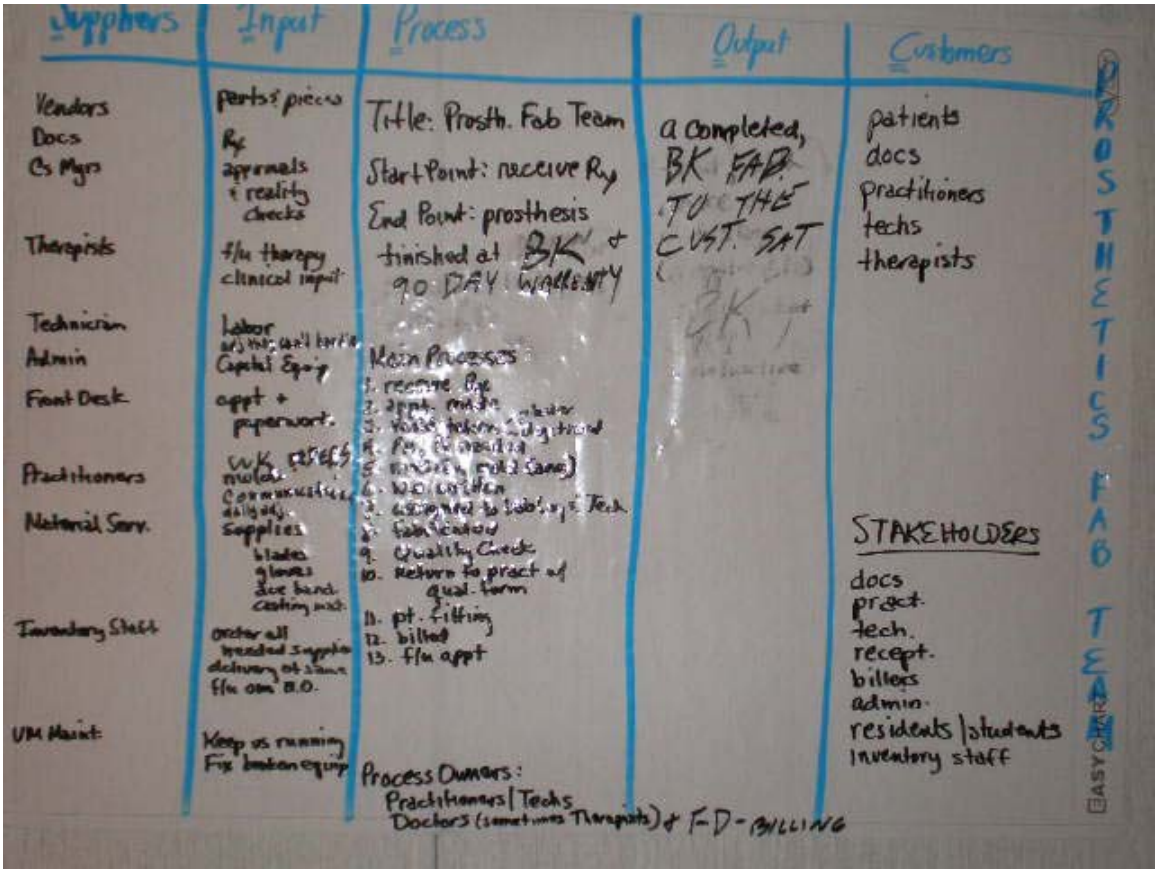
- 1912: University of Michigan Hospital began making braces (orthotics) in a building on Catherine Street in Ann Arbor, MI. At that time, orthotics was a part of the surgery department.
- 1918: Dr. LeRoy Abbott was established as chief of Orthopedic Surgery and began to supervise the production of braces. Dr. Abbott utilized the services of a carpenter, George Curry, to construct steel and leather braces for leg and spine support. Later, Dr. Charles L. Washburne of Orthopedic Surgery created a hip splint fabricated in leather by orderly, Pat Scully.
- 1924: Dr. Carl E. Badgley became head of orthopedic surgery and opened the Appliance Shop, which produced orthotic devices. This shop became an integral piece of the University of Michigan Hospital.
- 1930: The Appliance Shop moved to the lower level of the University Hospital.
- 1951: A hand splint and adaptive equipment section was opened in the Appliance Shop.
- 1958: The prosthetic unit was established and the shops were united in a 5,000 sq. ft. area on the third level of the University Hospital.
- The center moves many times before arriving at its current location on South Industrial Rd. in Ann Arbor, MI.

Appendix D



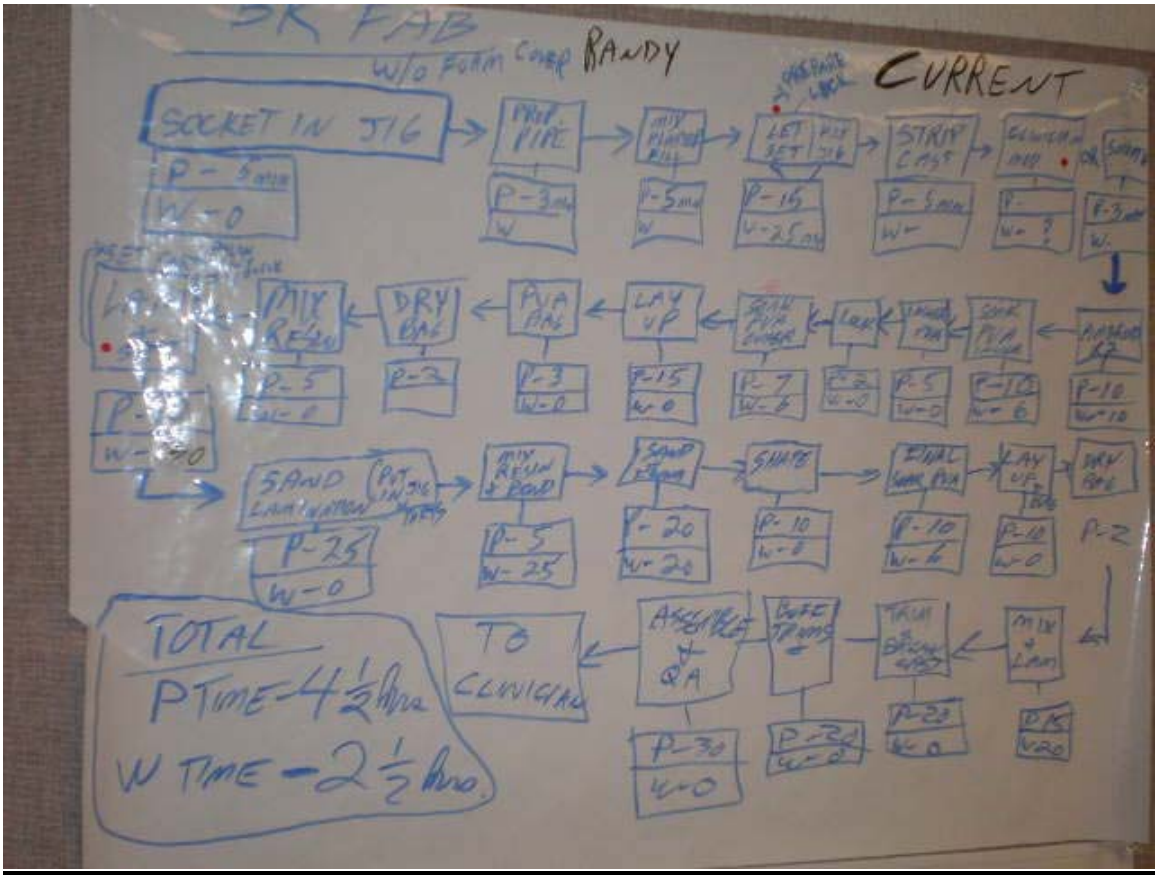
In/Out of scope diagram for prosthetics.

Appendix E



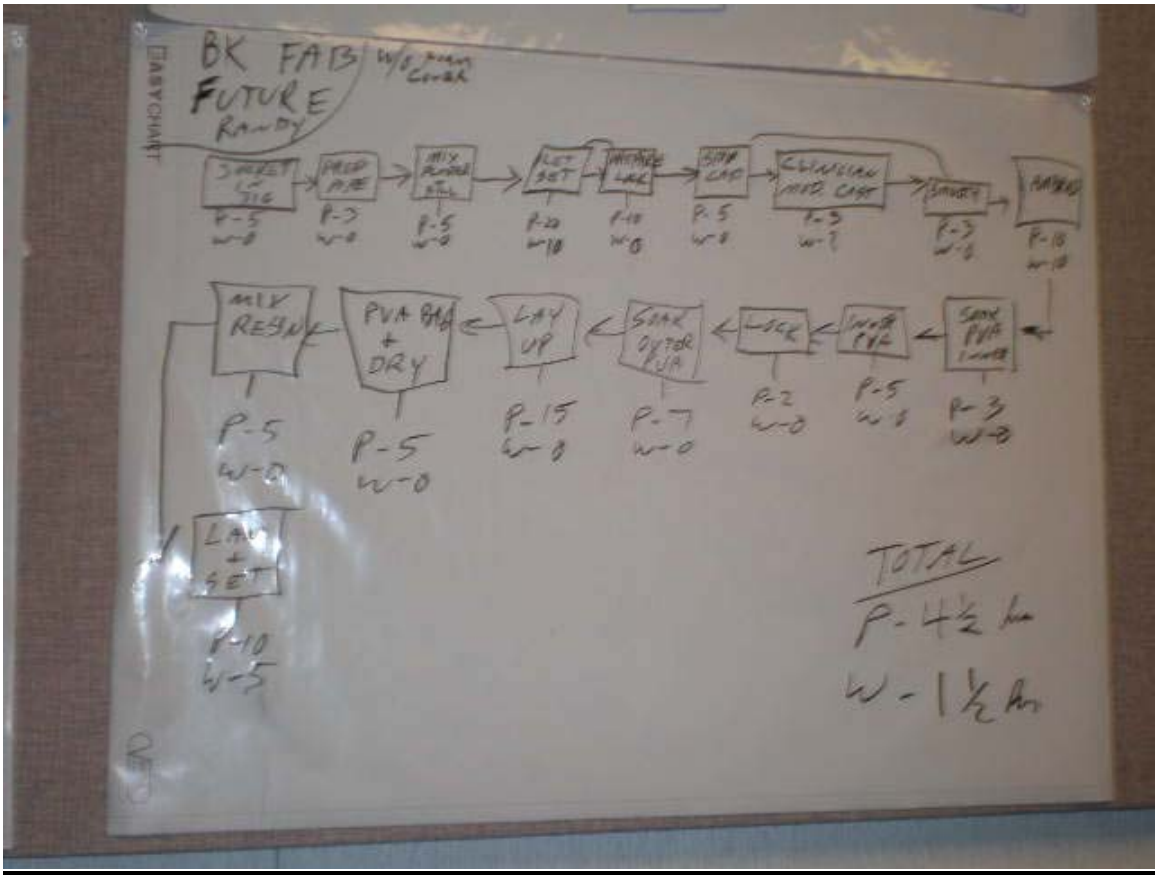
SIPOC for prosthetics.

Appendix F



Current state value stream map for Below Knee (BK) prosthses.

Appendix G



Future state map for Below Knee (BK) protheses.

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Signature Page

Implementation of Lean Principles at the University of Michigan Orthotics and Prosthetics Center based on the Implementation Method Outlined in *Lean Thinking*

By: Dana Lembrick

I confirm that this honors thesis is completed to my satisfaction and approve of its content.

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