

## **AC 2010-312: EXTENDING LEAN MANUFACTURING SYSTEMS THROUGH IMPLEMENTING MOBILITY (A CASE STUDY)**

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# **Extending Lean Manufacturing Systems through Implementing Mobility (A Case Study)**

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## **Abstract**

Lean manufacturing transformation has been adopted by many industries in the northern hemisphere including small businesses as a survival method against tough competition from low-cost labor markets. The lean manufacturing system is the final result of lean transformation. A lean manufacturing system is a manufacturing system that is characterized by low (Work In Process Inventory) WIP, material pull instead of push, and the use of kanban cards.

The heart of a lean manufacturing system is the cellular manufacturing [1]. Although cellular manufacturing has a proven track of success, it suffers a major drawback. That is, when the product and/or the product mix changes, a cell reconfiguration may be required. This leads to movement of heavy machinery inside the work area. Besides being a time consuming activity; it is a major contributor to employee dissatisfaction. This paper is based on extending lean manufacturing systems by enabling machine mobility through converting static machines into mobile ones.

## **Introduction**

The research in this paper is based on work done by two undergraduate students as their capstone senior design projects at Central Connecticut State University (CCSU) and Texas A&M University at Corpus Christi (TAMUCC). The work was not only intended to expose students to interesting projects, but also expose them to projects of high research value.

## **Research Value of the Project**

There is a great trend in industry in North America to adopt lean manufacturing as a means to face the fierce competitions from overseas and the low-cost labor markets. Although lean started from the Toyota assembly line, it has expanded enormously to include small to medium size businesses, small machine shops and was even extended to office work.

The main backbone of lean manufacturing systems is cellular manufacturing [1]. The principle of cellular manufacturing is to group parts into families. For each family selected machines are identified as being capable of producing (assembling) the corresponding family.

The main advantage of this approach is the close proximity of the different machines which in turn minimize handling cost and simplify the set-up. It is also a step in the right direction to promote the one piece flow, which is highly recommended in lean philosophy.

Many investigators, researchers, and productivity consultants indicate that lean strategies work very well with stable demand and/or large volume production [1, 2]. With today's environment and with the high turbulence and volatility of the international and local markets, these manufacturing cells become a cumbersome and additional burden on the company management since moving equipment is not a pleasant idea. Fig. 1 shows an example of large machine tool in the process of relocation.



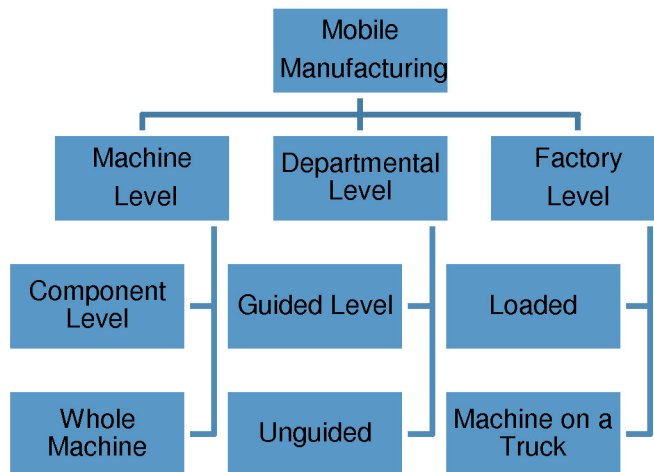
**Fig. 1: A frequent scene in a manufacturing company**

### Mobile Manufacturing

Mobility can be defined as the state where the Machine tool/system is equipped with internal/external tools to change the system to a different state in response to external factor. Some of the benefits of mobile manufacturing as listed by Ask et. al. [3] are:

- Entering new markets where there is a necessity to have a local production.
- Being able to share low frequent used production capacity with other companies.
- Covering occasional peaks in production.

Figure 2 from Gadalla [4] shows a general break down of the different mobility cases. Mobility can be classified into three main groups: Machine Level, Department level and factory level.



**Fig. 2: Different types of mobility**

### Machine Level

Machine level can be classified into two sub levels: component level and whole machine level. On the component level, part of the machine is movable or the machine is equipped with several tools (tools could be soft tool such as: computer programs that are upgradeable, or hard tool such as automation devices) to change machine configuration.

The whole machine could be movable. The benefit of this system is to move the machine to where the production is needed saving huge amount of transportation cost and time.

A mobile saw mill, developed by a company in Oregon, is an example of these systems. This machine is carried to the log to cut the lumber on sites saving tremendous amount of transportation. Another example is a mobile milling and boring machine that is carried to work sites, saving a lot of transportation cost especially if the workpiece is huge.

Another benefit of putting the machine on wheels is that the machine could be stationed anywhere in the shop saving a lot of transportation time inside the shop.

### Department Level

The department level mobility can be sub classified into: guided and unguided mobility. The guided mobility is where the entire machine (or the workpiece) is put on wheel and travel through the factory. AGV's assembly is a good example of this category. The unguided case represents the case where the machine level case grows.

### Factory Level

Factory level is where the entire company or part of the company is put on wheels. Factory-in-Box program is a good example of this type of mobility. Various cases and scenarios have been demonstrated through this project as an example: a cleaning and scrap grinding foundry mobile unit was designed and purchased to be used among several small businesses to offset the high investment of the unit.

### **Internal Mobility versus External Mobility**

Mobility can also be defined as internal and external. Internal mobility is where the machine tool is capable of using multiple manufacturing processes or using multiple tooling. External mobility is the state where the machine tool can physically change its configuration or being equipped with mobility tools to physically re-locate the machine to a different location in response to market change.

### Internal Mobility

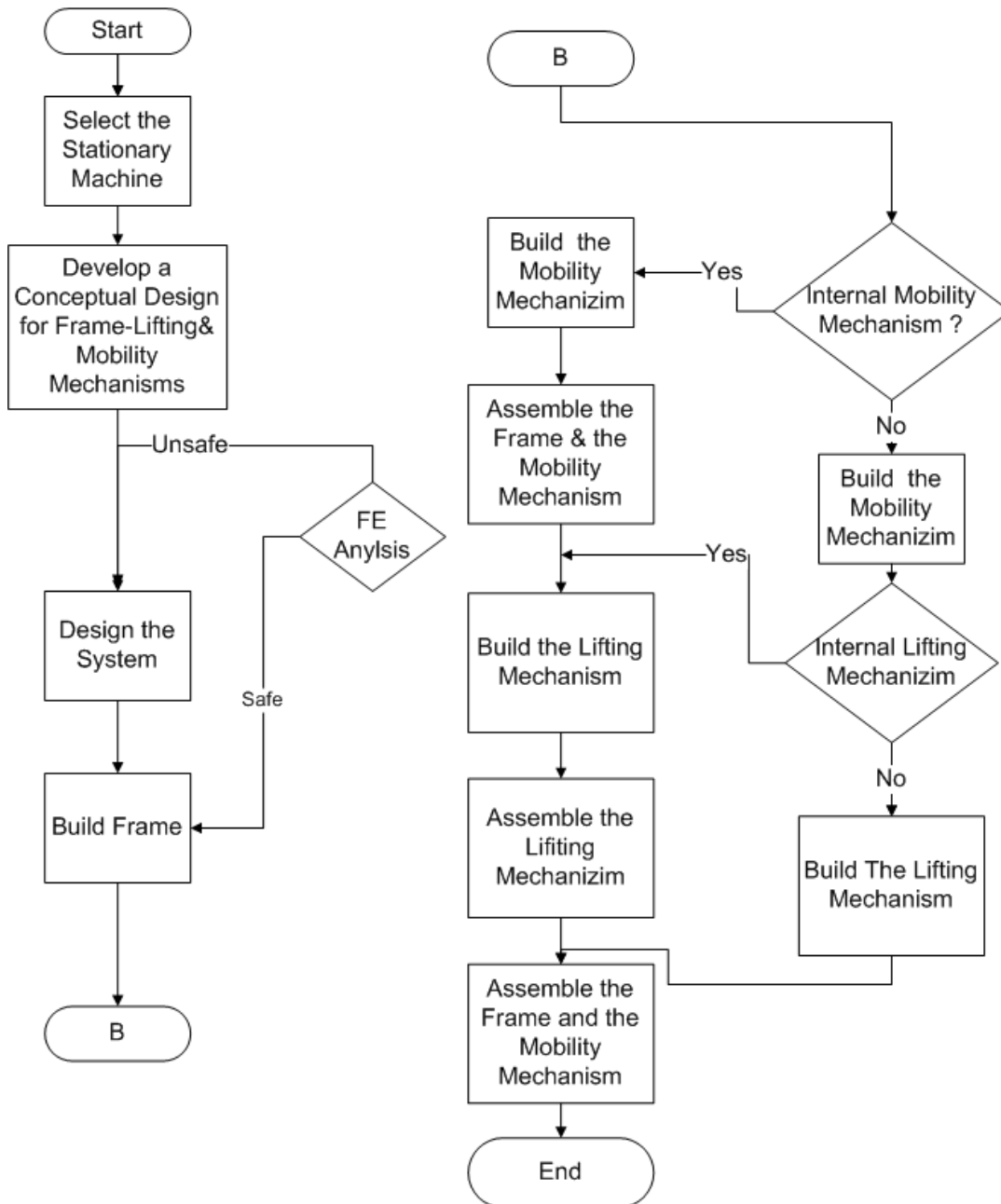
Examples of machines that can be characterized with internal mobility are: a Mill / Turn, Laser / Machining, Ultrasound / Machining, Laser cutting/Punch machines, etc. These machines are capable of changing the manufacturing process according to certain technical or economical consideration. Another example of internal mobility is the ability to use multi tooling, such as the min tool turrets, Multi Turn/mill tool, and mini-turret in sheet metal punching. Obviously the Multi tooling approach is less effective than combining two or more manufacturing processes. Obviously, combining the two approaches boost the economical and competitive advantage of the company provided that the human factor that is capable to operate them is available.

## External Mobility

External mobility can be defined as the ability of the machine to change physical characteristic such as changing configuration, and the fundamental way it is operated. As a result, it becomes more mobile, and finally changes its physical location using the machine own mobile tools rather than using external aids such as roller, crane,..etc. Reconfigurable manufacturing System (RMS) is a good example [5] for external mobility.

## General Framework for Designing a Mobile Machine

Figure 3 shows a flowchart given to students showing the detailed steps of how to progress in their work.



**Fig. 3 Steps to build a mobile machine**

## **Project # 1 Mobile Machine Mover of a Thermoforming Machine**

The goal of this project is to design and create a working model to move heavy equipment around a shop. A thermoforming machine shown in Fig. 4 was chosen as an example. The problem with heavy equipment in shops is that they become sedentary. When the time comes to move the piece of equipment around, it becomes a task that is not easily resolved. With the design of the mobile machine mover a lifting mechanism will be mounted in the base of the thermoforming machine. This mechanism will be easy to use and provide pneumatic pressure to high capacity casters to raise and lower the machine.



**Fig. 4: a Static thermoforming machine**

### **Design Guidelines**

#### **Safety**

Safety is always of utmost importance to all companies. If the product is not safe it will never be released for manufacture and most importantly could cause injury to anyone operating the piece of equipment. Since we will be working with heavy equipment safety will be our number one focus during this project. The frame that the thermoforming machine will be cradled in must be securely welded and attached to the casters and hydraulic rams as well. Forces will need to be calculated on exactly how much weight the frame and lifting mechanisms will be able to safely lift with a marginal safety gap as well.

#### **Cost Effective**

The mobile machine mover must be cost effective. It must be inexpensive enough to be justifiably installed on existing equipment. The prototype that has been built was very cost effective. Utilizing as much as we could from the shop less than \$100 was spent on this project.

#### **Reliability**

The mobile machine mover must be reliable. With a piece of equipment that raises and lowers heavy equipment reliability needs to be a major factor in the design theory. During the design phase we went as mechanical and simplistic as possible.

## Diversity

This lifting mechanism must be able to be applied to a variety of machines. With its simplistic design few alterations will need to be made to adapt to other machines.

## Project Details

### Frame Design

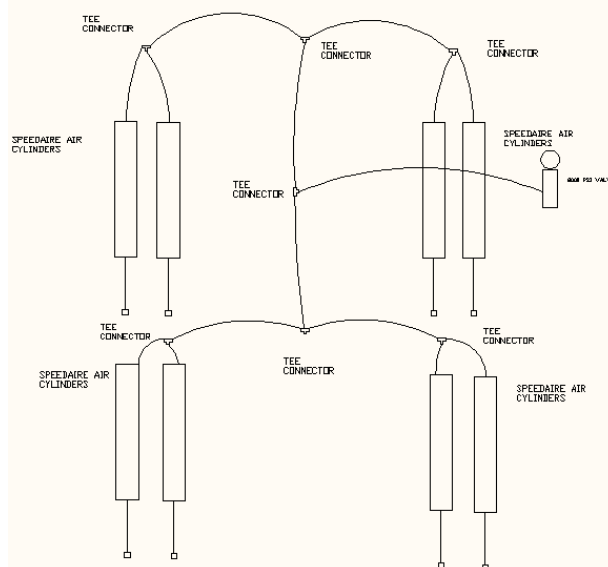
The simplistic design of this project allows few moving parts. The base frame sits underneath the base of the machine to be moved (Fig. 5). The base frame consists of angle iron and square tubing which the piece of equipment to be moved rests on. The lifting mechanisms are attached at all four corners of the base frame.



**Fig. 5: Base frame to hold the machine and to attach the lifting devices**

### Lifting Mechanism

The lifting mechanism (Fig. 6) consists of a SPEEDAIRE Pneumatic air cylinder attached to a frame supported by angle iron and ¼ inch flat bar. Below is a diagram of the pneumatic system.



**Fig. 6: Lifting mechanism using air cylinders**

The air cylinder pushed down on a hinged flat bar, (which in turn is connected to a caster) which creates the lift needed to get the machine off the ground. One of these lifting mechanisms is located at each corner of the base frame. This is the most simplistic design we came up with (Figures 7, and 8).



**Fig 7: The Hinged flat bar at each corner**



**Fig. 8: The four hinges after installation**

### **Project # 2 Mobile Sand belt and disc Machine**

To stay in business and be competitive in the manufacturing industry, companies have to produce the maximum amount of goods in the shortest period of time. Being cost-competitive sometimes pushes companies to relocate their facilities to areas where they can save in labor and other expenses related to production. Another approach for being cost competitive is using lean manufacturing tools. Regardless of the approach taken, the companies are still facing the challenge of mobility for their machinery.

A lot of researches have been done on the subject, and the technology is rapidly advancing. Today, the tools used are just as diverse as they are efficient. Among many other examples are the hydraulic toe jacks, mechanical forklifts and overhead cranes. Each tool has its advantages and limitations depending on the applications and the type of product being handled. Even though the key here is to find the right fit for your application, cost is the most important factor in the decision making process.

#### **Frame**

The moving device that we will be building in this project will replace the current way of moving the sand grinder, which is by lifting it up with a fork lift.

The basic geometry of the carrier will be modeled after that of the sand grinder. The main plate will have 4 L shaped brackets to restrain the machine from moving while being used. The L



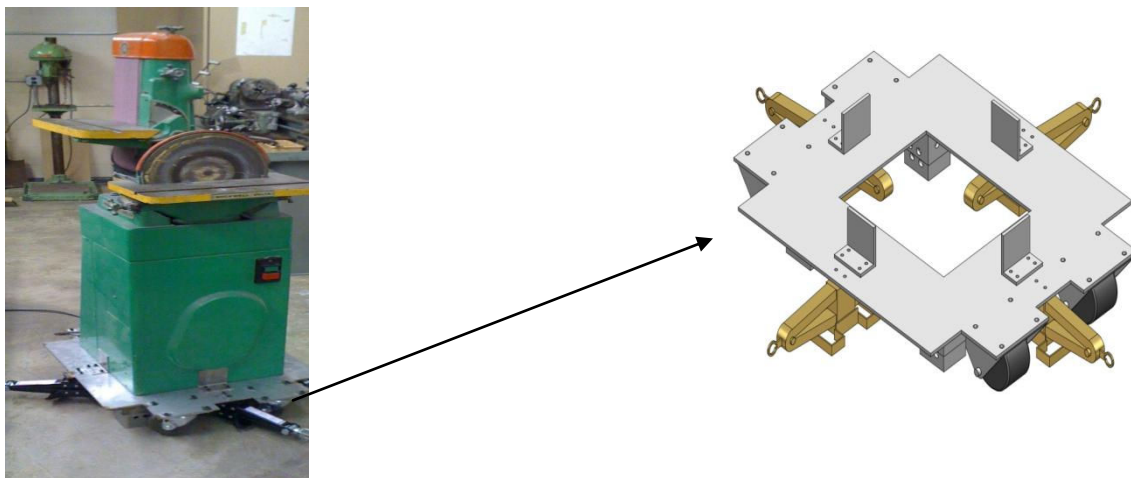
shaped brackets will be located on the 4 sides of the machine. Those are safety features to assure that nobody get hurts during a moving operation.

### Lifting Mechanism

The movement of the machine will be mechanical, and will be performed by 1 or 2 operators that do not need to be professionals in the field. The machine will be permanently seating on this device, and the moving features will be activated as needed. The device will be seating on its 4 legs while the legs extension are extended. To activate the movement, we will raise the machine using toe jacks, then retract the legs, and lower the device back to ground level. At this point the machine will be seating on its wheels. The wheels are normally raised up in air because their overall height is less than that of the legs with their extension.

One of the options explored when deciding how to raise the platform was to use a hydraulic system. Our system would have a small four-stroke gasoline engine that would be attached to an oil hydraulic pump. The pump would create a steam of high pressure oil that would go through a valve. The whole system would be activated by the operator actuating the valve. The hydraulic fluid would go through the fluid circuit and activate a simultaneous upward motion at four locations. After doing some research on the hardware necessary to put that system in place, we determine that the cost of the overall project was astronomically high, so the idea was dismissed. Also, using a pneumatic system would be another avenue to take, but we would be facing the same issue of cost. With the pneumatic system, as the operator activates the motion, the air sitting in the reservoir would be compressed by the piston and flow through the pipes to the four locations where the upward motion would take place. The third and last avenue explored was to activate the motion mechanically. This was proven to be the best solution in this case.

One of the biggest advantages of this device is that, not only it does not require hiring a rigger crew or moving professionals, but also it saves in time and is relatively cheap. Safety, cost and efficiency were the most important factors in this project. Since all this issues have been addressed, the end product makes the project a successful one.



**Fig. 9 The sand belt machine after conversion**

## **Conclusion**

Students were able to lift and maneuver the machines around the shop and set them down directly on the floor for stable use.

Students were able to design and build projects of high research value. In addition to recognizing the need for future work, they followed sound track of scientific reasoning. Such an approach would help them to develop higher problem solving skills. The experience they gained during these projects will encourage them to propose, undertake, and supervisor research projects. Thus contribute to create a category of workforce that is capable of developing innovative solutions and carrying them till implementation. It is worth mentioning that this workforce is highly needed for North American manufactures to become more competitive.

Future plans for the Mobile Machine Mover include; integrated power wheel for effortless movement about the shop areas, installing a GPS unit to pinpoint exact location of the unit, and using the GPS unit and power wheel together to remotely relocate shop equipment to designated areas about the shop with the push of a button. FE structure analysis will be also included in future work by the authors for better evaluating the structure integrity of mobile frame.

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## **Biography**

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