This research paper examines the various models adopted by our small and medium-sized manufacturing enterprises and how effective is the design of cells in high-mix low-volume assembly environments. It briefly introduces the process of cell design, the elements of this design process and how essential from a Lean manufacturing standpoint that would surface a list of challenges faced in making those elements work in a high-mix low-volume assembly environment. This paper is based on the assembly of mid to small-sized production units that are moved from one location to another with the assembly work being done standing as opposed to bench assembly of smaller parts.

Survey Question: Would Cell Design for your HMLV production environment be effective? (2011 / 2012 Survey of 50 SMEs)

YES	21 percent
No	47 percent
Not sure	32 percent

What is an Assembly Cell?

Production or assembly cells are commonly used in manufacturing facilities. Michel Baudin [1] defines an assembly cell as a set of physically linked machines or assembly stations where a family of parts is processed through a common sequence of process steps by a team of multifunction operators moving between workstations at a required pace which is autonomously controlled by the team. An assembly cell is thus a collection of different processes arranged in physical proximity to perform certain tasks – manual and/or mechanical. Operators are assigned to the cell to perform different tasks and the cell is required to produce parts at a rate fast enough to meet demand.

Several issues need to be considered while designing an assembly cell. The cell design process starts by identifying all the component parts required to build the unit and the sequence in which they are assembled. This knowledge gives information about the activities to be performed in the assembly process. These activities can typically be broken down into smaller tasks. These tasks are assigned to different workstations and/or operators within the cell such that the total workload among all workstations or operators is balanced.

Figure 1.1: Operator Workload Balance for Assembly Cell

Figure 1.2: Cell Workload Balancing Chart

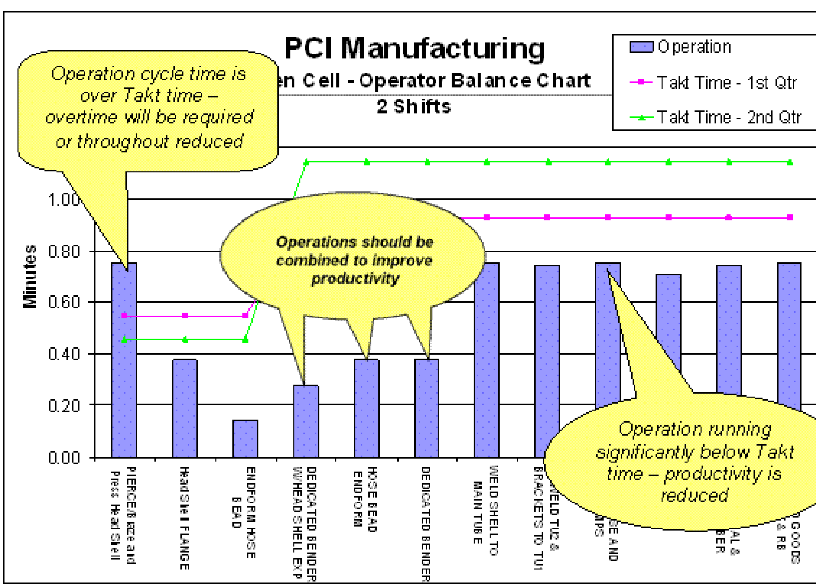

Figure 1.2 shows an example of the workload balance chart for a lean cell setup with up to five operators in a production line. The tallest bar on this chart is the constraint operation in the cell and the cell can produce units as fast as its longest operation (Op-1 in Figure 1.2), which is 0.7 minutes. This cell would produce 1 unit every 0.7 minutes and this rate is called cycle time of the cell. To determine number of operators to be assigned to a cell one needs to know the demand rate for that unit. This rate is called takt time in the Lean Manufacturing literature. The cell needs to be staffed such that its cycle time is at least as much as or faster than the takt time. While assigning tasks to operators, one also needs to iteratively consider precedence of assembly tasks, location at which incoming material is supplied, and the path traveled by an operator to perform several different tasks. This information is then used for determining locations of various workstations.

The objective of cell design is to assign assembly tasks to operators, determine assembly sequence, and define locations for workstations and material while making the most efficient use of manpower assigned to the cell ex. evenly distributing the workload among all workstations, such that all the bars in Figure 1 are of fairly equal height.

Information Requirements for Assembly Cell Design:

The following information needs to be available to design cells as per the objective mentioned above:

- Assembly bill of materials
- Time-study data for various tasks to be performed
- Precedence constraints for assembly tasks

Once the cell is designed to run with certain number of operators, the information on cell setup needs to be documented in a Standard Work document. Standard work is an important element of Toyota Production System (TPS) and Lean Thinking, which define it as the current most efficient way to produce product. TPS/Lean relies on following it religiously to reduce variation. The standard work document for an assembly cell would typically indicate:

- Number of operators used in the cell and cell's cycle time
- Assignment of various tasks to different operators, sequence in which tasks need to be performed, and the time required to perform them
- Location of various workstations and tools
- Type and quantity of different types of parts required for each assembly, material delivery points, and WIP location

Challenges of High-Mix Low-Volume Assembly:

The tasks involved in design of an assembly cell require thorough study of the product typically done by a person with specialized skills such as an Industrial Engineer. In a high-volume production environment, the large amount of time spent is justified because once the cell is set up it stays in production for a long time. On the other hand, a high-mix low-volume producer does not have this luxury for two reasons:

- The short-lived nature of the cell means the Industrial Engineers would be constantly busy designing cell setups
- The amount of time spent by specially trained Industrial Engineers is amortized over only a small amount of product. Thus, overhead cost per unit is quite high in a high-mix low-volume environment compared to the high volume situation

Thus, high variety and low production quantities make it difficult to apply/work what is an important element of TPS/Lean in a high-mix low-volume environment.

Solution for High-Mix Low-Volume Environments:

The solution to tackle this challenge encompasses two concepts:

- Identifying similarity among assembly tasks for different parts, and
- Using computation power to do much of data management and processing

The decision to build certain units in an assembly cell is made based on the similarity of assembly tasks performed to build that unit, even thought the units built are quite different from each other. One needs to take advantage of this similarity – at the assembly task level as opposed to part or unit level – to tackle the challenges of high-mix assembly.

High variety also means that the amount of information to be handled is very high. Because of this, manual methods used in low-variety “lean” production environments (such as kanbans, heijunka boards, etc) are typically inadequate in high-mix production facilities, and computational tools are often necessary to manage and process data. While employing computational tools in a high-mix environment, one still needs to follow the basic principle that Lean adopts when manual methods are being used: keep things simple. The computational tool developed needs to be simple to use by performing all intricate transactions behind the screen in order that the user does not get confused or overwhelmed by the display.

Case Study:

We developed a simple computational tool for a high-mix low-volume assembly cell in a store-fixture manufacturing company. This assembly cell builds store-fixtures that are produced as per customer demand. Each fixture is unique to each customer and there are very few common parts. But, the assembly tasks involved in building different fixtures in this cell are quite common among different units. We developed a database application using Microsoft Access that takes advantage of this commonality of tasks and produces standard work instructions for designing assembly cell setups

[1] for building different units with different takt times. The typical time required for producing one cell setup is less than 30 minutes.

The work done in developing this application can be broken down into four broad phases:
Step-1: Study of the cell and product mix
Step-2: Development of basic structure, data collection, and data entry
Step-3: Training of end-users
Step-4: Development of standard work documents as needed
The work involved in the first two steps is primarily a one-time activity and is done at the beginning of the project. Step-3 is performed at the beginning of implementation and additional training can be conducted as needed. Step-4 is generation of standard work documents as needed.

The first stage of the application includes studying the production cell(s) to be served by this application. The study begins with getting a list of all the units built in the cell. Once all assemblies made in the cell are identified, the next step is to study the components that make up these assemblies and then categorize the components into different types based on the activities performed with each component. The reason for classifying different part types is to be able to list all possible activities related to each part type. After identifying all the activities, the next step is to break each activity down into different tasks performed. Time studies are then conducted to find process times for these tasks.

In the second step, a database is developed to store information on activities, tasks, time-study results, etc. The same database can be used for managing that information for developing cell setups or a separate application can be developed for that. In Step-3, the end-users of this application are trained. This included training on reading the standard document as well as some concepts of flow, such as identification of constraint, understanding takt time & cycle time, cell setup times, etc. The user needs to be trained identify skills required for different operators and assigning operators to respective positions in order to utilize their strengths. The user also needs to identify the constraint operation in the cell from operator workload balance chart so that appropriate person can be assigned to this critical position, which determines the cycle time & hence throughput of the cell.

Step-4 involves generating the standard work documents. The user has to develop a new cell setup (and print corresponding standard work document) each time there is a new unit or change in the demand rate. Once a standard work document is developed for one unit to meet a certain demand rate, the same document can be reused until there is a change in the design of the unit or any of the task times have changed due to technological or operational improvements.

Benefits:

In the case mentioned above, we noticed two types of benefits:

- Improvement in cell's efficiency as measured by units produced per man-hour
- Reduction in cell setup changeover time between products

The improvement in cell efficiency results from better utilization of available manpower as the cell is balanced better. Variation in cell efficiency was also reduced overtime as the cell was set up and run according to a standard document. The improvement in cell setup time was also important since setup changeovers are quite frequent in high-mix low-volume assembly.

Limitations:

Every tool has its limitations and the application developed in the case-study is not without its own. One of the chief requirements for this application to be successful is to have a flexible cell that can be easily reconfigured as needed – both in terms of cell layout as well as breaking a job into different activities and assigning to different operators. Rigid cell layout with same level of task assignment could result in longer walking distances for the operators, which would increase cell's cycle time due to longer processing time at the constraint, operator fatigue, etc.

Summary:

This paper discussed the challenges faced by implementing a lean concept in a high-mix low-volume assembly environment and presented one solution to overcome those challenges. It is important to emphasize that most of the principles of Lean Thinking or Toyota Production System can be applicable to a high-mix environment, but the methods are not. This requires us to invent new tools and methods to benefit from lean principles in high-mix low-volume environment.

References:

Baudin, M. 2002. Lean Assembly: The Nuts and Bolts of Making Assembly Operations Flow. Portland, OR. Productivity Press, Inc. ISBN: 1563272636.

[1] A cell setup gives information about number of operators required, the assignment of tasks to operators, and locations of workstations, incoming material, and WIP units.