Toyota Production System
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Lecture - 29
Flexible Manufacturing System

Welcome friends in our last 2-3 sessions we have discussed some topics which are beyond Toyota production system. The name started with lean manufacturing which is more or less Toyota production system, where we talk of how to eliminate waste. So that is one important aspect of Toyota production system though it is not the complete Toyota production system but one very important subset of TPS is lean manufacturing, which is focusing on elimination of waste.

Then we also discussed in our previous sessions about it is also very important to have an orientation towards your customers and when we have that external orientation then it becomes agile manufacturing. So you have lean manufacturing which is focusing on how to eliminate the waste, then how to full fill the requirements of customer, how to become responsive to the needs of the customers that is the idea of agile manufacturing.

And then we also discuss that environmental pressures are also coming on the manufacturer. It is very important that we do our manufacturing in such a way that it should not create any kind of negative impact on the surroundings and it should also help us in conserving, preserving our natural resources so that our next generations can also use those resources for their prosperity.

So that is sustainable manufacturing. So you see there are different types of pressures coming on the manufacturing people. They have to see how to minimise the cost by following the principles of lean, then how to become a customer oriented marketer that is agile manufacturing and then how to have a sensibility towards the external environment and all these things are very much necessary.

We discuss last 2 topics, agile and sustainability more from the external orientation and in which we were largely influenced by the ideas of marketing management. We were influenced by the idea of sustainability, but there is one more term which we need to discuss

because when we are talking of agile manufacturing which is becoming a customer oriented, customer responsive manufacturing.

At the same time there is a technical version of that, more manufacturing version of that that is flexible manufacturing system. In this particular session we are going to discuss the concepts of FMS that is flexible manufacturing system. Nowadays we all know more and more automation is taking place, industries are becoming automated, industry 4.0 is just knocking on our doors.

Cyber-physical systems are going to replace lot of human machine systems. So therefore this flexible manufacturing systems are going to be very important things in our, you can say coming manufacturing environment and therefore what are the elements of FMS, how FMS can be adopted in the organisations and how FMS can be adopted in countries like India. Where large number of small and medium organizations are having the issues related to capital investment.

And that is the major challenge for improving the productivity of these organisations. If you talk at the OM levels, so because of large resource availability at the OM level you can implement any new technique, but again since we have gone through the course of Toyota production system we have understood the meaning of various principles of TPS.

We also know that we should not adopt any technology because it is new unless, until you have a reliable technology, a verifiable technology, when the technology has already well-established then should you use that technology. So that is what we are all going to discuss in this session of FMS. Now when we are talking flexibility, FMS. The core idea of FMS is the concept of flexibility.

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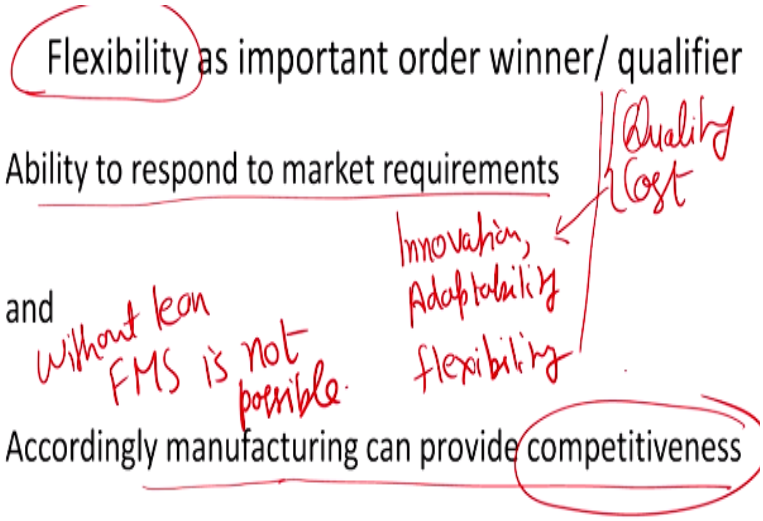

Now as in the past our issues related to quality, cost were very important, but now in our discussions we have seen that these days we talk more of innovation, we talk more of adaptability and we talk more of flexibility. So the time is, the earlier order winners and qualifiers quality, cost, on time delivery, these order winners, qualifiers are now moving into the direction of innovations, adaptability, flexibility et cetera.

And therefore the meaning of flexibility is ability to respond to market requirements that is one dimension of flexibility that how you are able to respond to various market requirements and then with respect to manufacturing how it translates, accordingly manufacturing can provide competitiveness. If your manufacturing setup is able to respond to market requirements without difficulty and that it only possible.

You see again it is very important to understand that without lean FMS is not possible because when you are having lean system you have eliminated waste in your organisation and then only you develop this ability to respond quickly to the market requirements. If you are having a bulky system where lot of waste is there, it will take lot of time to change as per the requirement of the market and by the time you change your system for today's requirement it will be too late and then market has further moved ahead.

So therefore it is important that you have a smart system, you have a lean system where no waste is there and as per the requirement it should be able to adjust, it should be able to provide those requirements and therefore we say that if you are having this ability to response

to market needs you get additional competitiveness. Because whatever is desired you are ready with that solution. So that is what we expect in this era of marketing.

So flexibility is going to be a very important order winner in the coming generation. It is already becoming very very important but in times to come it will further take a very strong driving stage in making your business successful. Now when we define flexible manufacturing system FMS.

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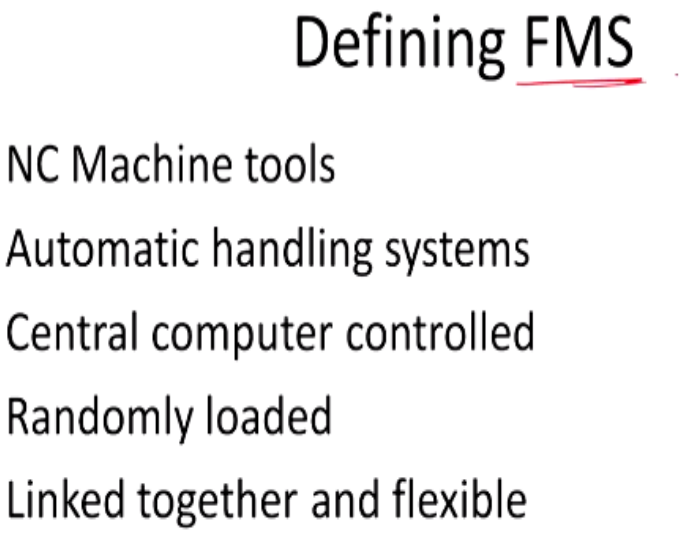

Now what are the different components in the definition where we say that yes this company has flexible manufacturing system. Now there different types of things which we expect that should be there in a FMS environment like you have more numerically controlled machine tools. Numerically or CNC, computerized numerically controlled machine tools, so that is one very important aspect that most of your machines are numerically controlled where manual field is not required.

So you can feed those machines, the input to the machines can be provided by some computer or by some other kind of memory device so that you can repeatedly change the programs, you can make only single piece depending upon what is the requirement. So the first important essential item without NC tools without you can say CNC you cannot have FMS.

Though there is an extreme side of this decision also. If you go back around 150 years back and you go to that craftsman era, that craftsman era is also a very good example of FMS,

where there is no system of mass production and when there was no system of mass production so craftsman was producing each product as per the requirement of an individual. So that was a system where no NC, no CNC was applicable.

But because of involvement of individual who was providing that product everything was done using the hands, hand tools, so it was also a kind of a flexible manufacturing system, but the limitation was that because everything was done by hands there was limitation of productivity. So you cannot do too much of work in a single day. So you can produce only limited amount of output by your hand tools.

So that was down side, we require more products and more variety also, so when more products, more variety is there so therefore we in present era talk of NC and CNC machine tools, but that is if you minus the productivity issue in our discussion so even the craftsman era also provide good FMS environment. The only environment which is totally anti-thesis to FMS is the mass manufacturing environment or the continuous production systems.

So continuous production systems, mass manufacturing, these are against the philosophy of FMS, but if you go to that tool room, you go to that system of craftsmen that is nothing but FMS only. Then because productivity is also very important nowadays, automatic handling systems, automated guided vehicles, AGVs are again required in a FMS environment. Central computer control system so that from a central server you can control your machine tools.

You can control your loading, unloading activities, you can control your handling system. So all these things can be controlled using a central computer system and it is going to happen in industry 4.0 that by a centralised control you will be able to control your entire operation. There is no need of human presence on each machine. You will have some kind of robots and all those robots are completely controlled.

And all those computers are again connected to a central server that may be through lan, maybe through some wide area network, maybe through some other network. So they are something like which is going to happen in our industry. Then you can have random loading system where you do not follow any particular schedule. So in our system of manufacturing right now we have a complete chapter on scheduling.

That how you are loading various machines, but in a FMS environment you may not follow a predefined loading system. You may load your machines as per the changing requirement of the customer. So like for an example if you go to a restaurant like Dominos pizza, in that Domino's pizza you keep some items readily available because they are the base product, but once the order comes only then you finally make that type of product out of that raw product.

So that is kind of random loading because customers will give different types of orders and accordingly different machines will be used for preparing those order. So random loading is keeping so that you do not follow any schedule and all these things 1 to 4, your machine tools, your handling equipments, your loading, unloading equipments, your central systems, your loading systems all these are having a kind of linkages with each other.

So there is a synergy also you do not require separate control for all these different entities in your manufacturing environment. All these things can be controlled at the same time. So that is another important thing with respect to flexible manufacturing system. So once we understood the meaning of FMS that what are the characteristics of FMS then in a standard FMS, standard flexible manufacturing system what are included.

Now it includes a number of workstations as we just discussed NC, CNC machines that can perform a wide range of operations.

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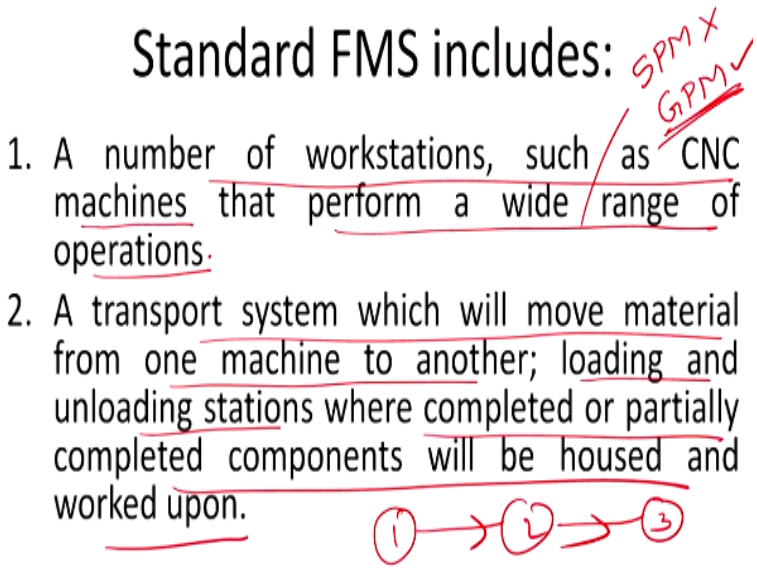

So you have machines which can perform wide range of operation. So here I would like to say that there are 2 types of machines, one is SPM and another are GPM. Special purpose

machines and general purpose machines. In our FMS we use general purpose machines not SPM, special purpose machines. Because special purpose machines are used in mass manufacturing environment.

Where you are repeatedly producing only very limited variety. So you develop special machines which can produce only one type of profile, one type of product or a very limited type of product. In general purpose machine you have a possibility to change the setting of machine each time you make a new product. So from the same machine you can produce variety of products.

So FMS is only possible when you have general purpose machines. With special purpose machine please remember FMS is never possible. That is one important thing in any standard FMS. A transport system which will move material from one machine to another, loading and unloading stations where completed or partially completed component will be housed and worked upon.

Now one thing is your NC, CNC controlled machines and which are having general purpose operations. So you can do any kind of threading, you can do any kind of milling, you can do any kind of facing, you can do any kind of other finishing operations as you program the machine that type of operation will be, that type of profile can be generated. So that is with respect to the first part.

Now the second part we need a transportation system so that you can move your work in process from one machine to another machine and that also is available in all the direction. It is not necessary that all the time products flow from 1 to 2 to 3, if this type of system is there that you have a well defined sequence of flow of products from one machine to second machine to third machine that again this is not FMS.

In FMS as per your requirement you should be able to move products maybe from 2 to 1, may be from 3 to 1 whatever is the sequence depending upon the various sequence of operations you need to perform you should be able to load, unload, move the products in between. So that is another important activity rather characteristic of any standard FMS system.

The third important standard thing which has to be there in any FMS system is a comprehensive computer control system which will co-ordinate all the activities.

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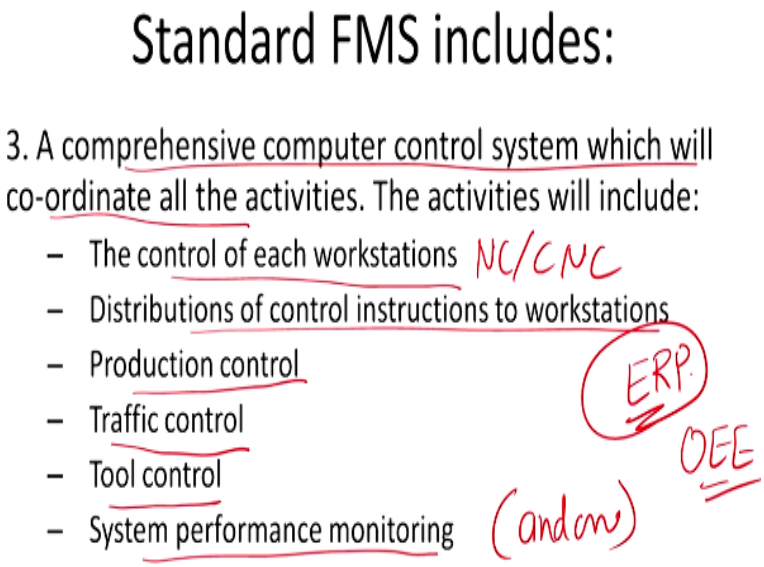

A central server as we were discussing that central console is required so that it will help in coordinating everything. You have railway reservation system in the country. So there is a central server and through that central server you are able to co-ordinate so many passenger reservation systems in different parts of the country. Rather nowadays because we have internet based reservation system.

So all of us are able to do the reservation on our computers, laptops, et cetera and all these things are coordinated at a central location. You do lot of work on emails, we do lot of work on other kind of social media platform. So all these companies they have a central location of their computer system and that central location is able to co-ordinate at all the points wherever activities are taking place.

So the same thing is required in flexible manufacturing system also and what type of activities we need to co-ordinate like control of each workstation. We discussed NC, CNC machines so that we need to co-ordinate. The distributions of control instructions to workstation, what type of job, what type of profile they need to do that is also a very important input we give to all these workstations.

The production process control, how many units to be produced, the traffic control so that there is no excess queue in front of any machine, the tool control, the proper feed of the tool,

the tools characteristics whether excess wear and tear has taken place in the tool, when to replace the tool all these things are to be controlled by the central system.

System performance monitoring, the most important, that this central system helps us in developing the andon. If you remember in one of the class we discussed that Toyota production system believes in having visual controls and these visual controls are andon. So to develop andon so that just by seeing those LED screens you are aware that what is the performance of my system.

Whether you are getting enough OEE, overall equipment efficiency and that kind of system you need to install with the help of the central control system and therefore whenever we are talking of FMS, the discussion related to ERP also becomes very important. When you have centralised planning of entire resources, when you have this enterprise-wide planning you are not doing planning for different sections.

Therefore all those things which are talking in terms of collaboration, in terms of integration of functions these things are actually useful or include into the standard FMS on any organisation. So FMS as we discussed becomes a choice of process when we need to discuss that what type of process you want to have.

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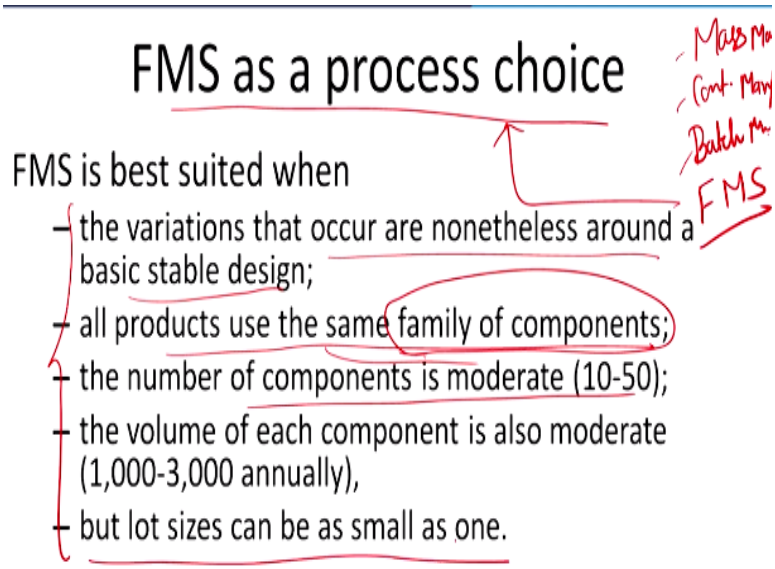

So FMS is a actually process choice, you can be a mass marketer or mass manufacturer, you can be a continuous manufacturer, you can be a batch manufacturer and then you can be a flexible manufacturing system organisation also. So all these are the different types of

processes and therefore we say that FMS is a process choice. So what we do in FMS that we have already discussed.

But when it is suited, what are those conditions in which flexible manufacturing system is giving good results, so the variations that occur are none the less around a basic stable design. So there is a basic stable design. We discuss the case of pizza. So there is a basic ingredient that base of a pizza and then depending upon your taste you give order of a particular type of pizza.

So there is variations around a base design. So when these variations are around a base design you can involve flexible manufacturing system. Then all products use the same family of components. Again this pizza example is useful in discussion of this that though quantity of different type of ingredient depending upon your taste may change but almost all pizzas use similar kind of ingredients.

So same family of component means the similar kind of ingredients, these are used in this flexible manufacturing system. In many educational institutions we have this kind of system that you have lot of flexibility in choosing your elective courses. So what we do that we provide some core courses that if you are doing MBA degree, so these are the core courses which are essential to have MBA degree.

And apart from that we give you a basket of elective courses and out of that basket you can choose anything which you like. So you are using almost similar kind of things from one family of component. So you are taking products out of one basket to make your MBA degree. The number of components is moderate. That these components which are given to you to select these are not infinite in numbers.

Like normally it is between 10 to 50, so this example of designing a course for yourself is a perfect example for FMS. Then the volume of each component is also moderate. Though theoretically speaking we say that in FMS we should be able to produce even a single quantity also, but practically speaking you normally have 1000 to 3000 units of order for one particular type of product design.

And lot size in which you will be making these products 1000 to 3000 annually that lot size can be of 1 unit also. That in a year you will be making lets say 2000 products, but you are not going to make all those 2000 today itself and keep those 2000 readily available in your inventory and whenever customer comes you will distribute that product. So that will go into the push philosophy and we are not talking of push right now, we are talking of pull.

So you keep some modular things ready, but you postpone the finishing of product till order comes and you know that finishing of product needs some kind of additional components which are coming from the same family of components which are used for other products also. So it becomes for you quite comfortable easy so that you can automatically without much efforts fulfil this objective and therefore it becomes an example of FMS.

So what are the benefits of FMS. We understood that if you have FMS in your environment it is going to help you in achieving the customer satisfaction. Because you are addressing the customer requirements in a very effective manner so that benefit goes without any other discussion.

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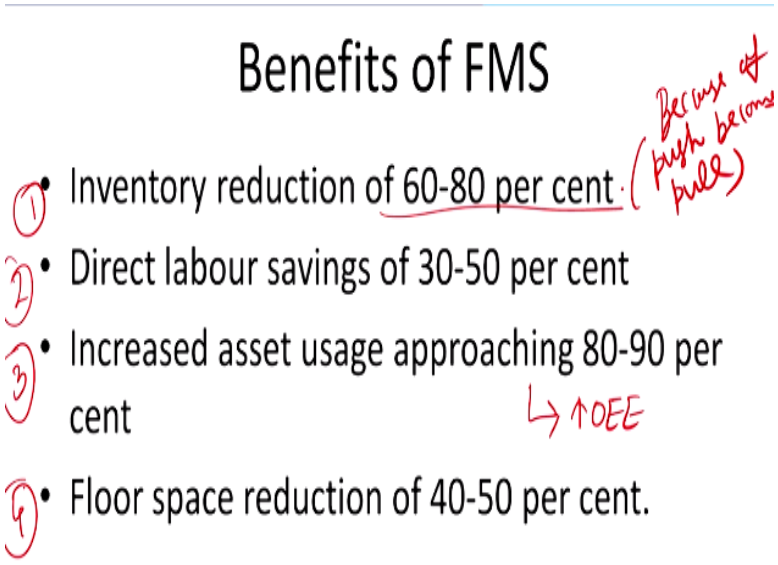

So now some other important thing which are you can say direct tangible benefit of FMS. One direct tangible benefit of FMS is the inventory reduction of 60% to 80%. Because of FMS your inventory will reduce up to 60% to 80%, because you will do everything because of push becomes pull. We are doing everything the final preparation of order is happening on the basis of pull philosophy.

So you will reduce your inventory level considerably, particularly inventory of finished goods will reduce considerably you will have some WIPS which are waiting for final order to come and as final order comes you will make that product according to the wish of the customer. So that is one direct significant benefit of FMS. The second benefit of FMS is direct labour saving of 30% to 50%.

You can plan your activities in such a manner that you will have a savings of 30% to 50% in the direct labour because you are not doing overproduction now. So when you are not doing over production you are not doing over processing you are maintaining only a limited stock of some WIPS so therefore you are able to save some extra labour which you are incurring so far.

The third is increased asset uses approaching 80% to 90%. So your plant utilisation, the efficiency inside the plant becomes very high and this will also lead for higher OEEs, higher overall equipment efficiencies. Because more users will promote more productivity and more productivity will translate into higher OEE. So that is also a direct benefit of flexible manufacturing system.

And then the floor space reduction of 40% to 50% that also happens because of limited inventory availability, because of no finished products remaining idle because of less use of direct labour, all these things will actually translate into lot of empty space in your plant. So your floor space uses also reduces considerably maybe up to 40% to 50% if you follow flexible manufacturing system.

Now how this manufacturing flexibility is obtained. So if you see that it is a process in which we need to apply things from two direction.

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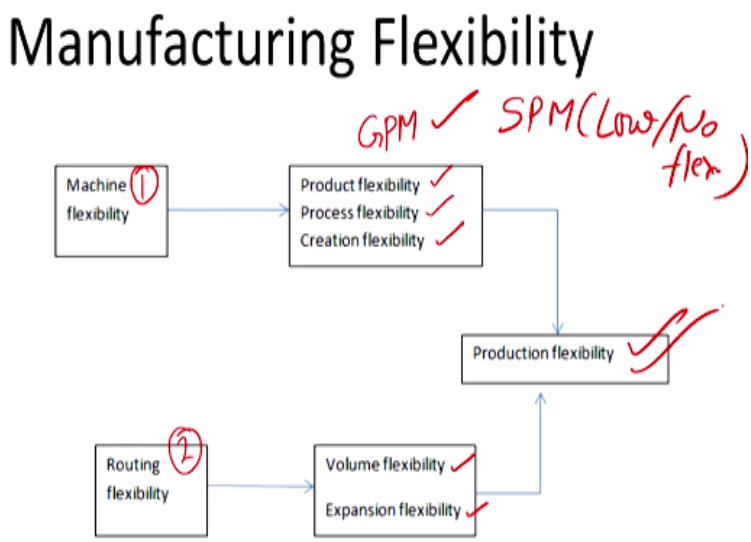

There are two types of flexibilities we are talking here. One type of flexibility is machine flexibility and the second type of flexibility is the routing flexibility. Now in the machine flexibility we have 3 components that your machine should be able to produce different types of products, it should be able to do different types of processes and it should be able to handle creation flexibility.

And routing flexibilities are volume flexibility and expansion flexibility that whether you are root you are handling equipments handle only a particular level of quantity or they can handle a spectrum of quantity. So if you have spectrum of quantity handling that means you have more flexibility. If you can handle only a particular level of quantity that means you have limited or no flexibility.

Similarly with respect to machine flexibility how many different types of products your machine can make and obviously if you have GPM you have higher flexibility, if you have SPM you have low or no flexibility. So these are 2 types of flexibilities and finally when I say the production flexibility we require machine flexibility also and we require routing flexibility also.

That you can change the sequence of operations without much difficulty that is routing flexibility. You can handle multiple levels of quantities, whatever level of quantity is required that is routing flexibility and your machine can produce variety of products. It can be used either for knurling or for facing or threading that is the process flexibility and it can create different types of products.

It can create jars, it can create bottles, it can create other kind of handling equipments. So different types of products can be created on the machine. So that is production process and creation flexibility. With respect to routing we have one flexibility of volume and another is of expansion. So all these types of flexibilities are required to have your production flexibility.

So that framework is very very useful in understanding to achieve the flexibility in your organisation and if you understand that how these flexibilities are achieved it will actually create a more manufacturing system which is very close to the markets requirement and you will not have issue of quantities, you will not have issue of a particular lot size because we discuss that FMS is suitable when you have lot size of even 1.

So if you are going to produce in single quantities like techniques like 3D printing. If you have that 3D printing it will provide you all these types of flexibility. So 3D printing and routing flexibility is by AGVs, automated guided vehicles. So if you have a 3D printing and AGV in a manufacturing environment you can say that to some extent you have production flexibility.

It is again important thing to know that it is difficult to say that flexibility in terms of yes or no. It is a matter of a spectrum that you may have limited flexibility or you may have some higher degree of flexibility. So flexibility may range from some low level to some high level. So it is a relative concept that how much flexibility is there in X organisation versus Y organisation.

So that is also important thing that flexibility cannot be measured in absolute terms. Flexibility is more like a relative term that Toyota company is more flexible than some other Indian company so that is how we say that it is a relative concept of discussion. Now if I say that what are the market requirements in terms of flexibility. So market requirements in terms of flexibility are.

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Market requirements in terms of flexibility

Product Variety	More different models, styles, colours etc.
Product customization	Increasingly tailoring products to suit a particular customer's requirements
Product innovation	Frequent changes of model and introduction of new products to the marketplace
Delivery flexibility	Delivering on short lead times and in quantities to support customer needs, not manufacturing efficiency
Demand flexibility	Coping with seasonality, fashion and other types of demand variation- matching capacity to demand

Product variety, product customization, product innovation, delivery flexibility and demand flexibility. So these are the 5 different dimensions of flexibility with respect to market and their meanings are when I am talking about product variety you can understand that offering different models, styles, colours. Product customization which looks very similar to product variety, but there is a minor difference here that increasingly tailoring products to suit a particular customers requirements.

In product variety we offer on our own more number of variants of my product, but when I am saying the product customization I am trying to develop product according to individual customers requirement. Product variety is more suitable when we are talking of a push organisation. Product customization is more applicable when we are talking of a pull organisation so that is to be seen.

Product customization is very difficult, it is almost 0 in case of a push organisation. So push organisations which are preparing their products in anticipation of the demand cannot go for product customization. Then third is product innovation. Now frequent changes of model and introduction of new products to the marketplace. So product innovation is a very important dimension of innovation also.

And it is an important aspect of flexibility as well that we want new products coming into the market and those products which are creating some kind of social impact that these are known as product innovation. Delivery flexibility, that delivering on shortly times and in

quantities to support customer needs not manufacturing efficiency. Particularly we should be able to understand that we are there because of customer.

So what number of units customer is requiring we should be able to offer our offerings to that particular customer. If I say that I cannot give you 50 units, I can only give you 100 units, now customer is requiring only 50 units, so why a customer should pay for those additional 50 units, which the customer is not requiring.

Like these days in our country we are having a movement of TV channels where it is being said that you should pay only for those TV channels which you want to see. Why are you paying for other channels which you never see and that is what delivery flexibility. So now whether my service provider can provide me that is flexibility, that if I select only some 10 channels and their monthly rental comes lets say 50 rupees.

So can that service provider will offer me service on 50 rupees if the monthly rental is just 50 rupees. If he says no, whether you take these channels or not these channels you have to pay minimum 200 rupees to me so that means that service provider has a constraint for delivery flexibility, that is important thing and then demand flexibility.

The demand flexibility means coping with seasonality fashion and other types of demand variation matching capacity to the demand. You have some capacity and the demand is something else. So now how you are able to match with those varying level of demand, can you fulfil additional requirement or if the requirement is not there how will you use your additional capacity for generating some extra revenue for your organisation.

So if your system has that type of flexibility it is known as demand flexibility. Demand may vary from here to here, but you have some kind of things to do so that you can generate enough revenue from other extremes also for the growth of the organisation. So these are the meaning which are more in the context of market for flexibility and with this discussion of flexibility we come to end of the session and that's how we discussed very close you can say linkages between lean, agile, sustainable and flexible manufacturing system.

Manier times people get confused because of so many names associated with manufacturing but there is some amount of difference between all these terms and they have a very strong

bonding also so because of bonding people get confused, but we need to understand what are the differences and what are the similarities and therefore how it is suitable, how these things are to be implemented in my organisation. So with this we come to end of the session. Thank you very much.