Indian Electrical Motors Limited[1]

As part of a corporate level thrust, Indian Electrical Motors Limited (IEML) is expanding its manufacturing activities in greenfield sites in Central India. Large electric motors for Railway traction are proposed to be manufactured at a location near Indore. The company has decided to go it alone, as far as the technology is concerned, as motor manufacturing has always been a core business activity in the group and it has been competing in the Indian market for a number of years.

IEML started operations in 1950, with a small plant manufacturing ceiling fans and AC motors. In the decades that followed, it expanded its range of products, and opened plants to make switchgear and control equipment in the 1960's, transformers, DC motors and pumps in the 1970's and a range of products such as vacuum interruptors, industrial electronics products, signalling systems and instrument relays in the 1980's. In the 1990's IEML has ventured into the areas of telecommunication equipment, and power transformers and has entered into joint ventures for manufacture of micro-motors and lithium batteries.

The corporate strategy of IEML is to retain technological control of those businesses in which it has demonstrated core capability in the past. It had consolidated its businesses into Business Groups (namely Motors, Consumer Appliances, Swithgear and Control, and Transformers and Projects). IEML realigned the business slightly in 1996, by merging the Transformer Division with the Switchgear and Control Business Group, now called Power Distribution group, and expanding the scope of the Motors Business Group, now called Industrial Systems Group.

The Industrial Systems group remains at the heart of IEML's business after all this diversification and in 1998, it accounted for more than Rs 400 crores of the group turnover of Rs 1800 crores.

Traction motors

One segment of business within the Industrial Systems group is the high capacity range motors. These are motors rated above 350 Horsepower (HP), and have been part of IEML's product portfolio for a long time. Within this area, in India, a well-established market is for railway traction motors, used for hauling passenger and freight trains. This activity is still a growth area, despite having reached a natural saturation level in many other countries. These motors are assembled as part of electric locomotives in the railways own production unit in Chittaranjan, in West Bengal. The railways is the sole customer for this product in India, but export opportunities, again usually through locomotives supplied by the Railways to other neighbouring countries is also possible.

IEML has negotiated the supply of 500 HP motors 1998-1999 and for the next 5 years. As of current prices, each locomotive costs about Rs 6 crores. These are for normal duty operations, and the top of the line in India is the state of the art 600 HP 3 phase AD Tranz locomotives, which cost about Rs 30 crores each.

Competitors:

The market segment for high-end motors is marked by worldwide excess capacity, with saturation of major traditional rail transport markets in many developed countries. Large multinational players such as Siemens and ABB are in this market, worldwide. ABBs transport business (now ADTranz) has already begun a high profile supply of 600 HP 3-phase state of the art locomotives to the Indian Railways, the major customer.

[1] This case is prepared by Narayan Rangaraj, IIT Bombay, in 1999

In India, the major competitors are the public sector giant, BHEL, which has a traditional presence in the heavy electrical machinery and traction equipment industry, Crompton Greaves, Larsen and Toubro, Indian Electrical Motors, Kirloskar and some other large groups with the potential for diversification. With the pressures of increased global competition in many of their strengths (such as power plant equipment), BHEL is in no mood to give up on their strong presence in this segment. Other multinationals such as Hitachi entering the market also cannot be ruled out.

IEML has a marketing collaboration with HexFG of Japan in the new plant through which the dealing with the railways is much smoother. This is because the railways prefer to deal with proven technology, which has been extensively tested. A trading alliance with a large diversified firm in Japan, for the purpose of raising capital and the expansion plans are set to take IEML among the top five players in the high rating segment of the market.

Technology Processes

Manufacture of three phase induction motors is an activity which IEML has been involved in since 1955. A motor consists of a housing (usually cast and machined from iron), a stator assembly, a rotor assembly and the endshields. The diagram of a typical induction motor is shown in Exhibit 1.

The key manufacturing processes are summarised below:

<u>Housing:</u> Raw castings from foundries are shot blasted and painted. They are rough machined, at which point casting defects such as blow holes and porosities are detected. If the casting quality is acceptable, it is further machined to fine tolerances (an excessive air gap when the assembly is made results in poor efficiency of the motor and also acts as a potentially dangerous flame path in the event of a spark.)

Typically, the machining of the housing, with all the faces and the bore and several holes for fastening and other purposes requires about 3 to 4 machining stations, with special purpose machines or sometimes CNC machines. Even with such machines, there is a limit to the size variety that can be machined at a single work-station. The typical change-over time (within a size range) is of the order of an hour (for replacing the fixtures and for making the measurements and settings for geometric features of machining, such as concentricity.)

<u>Rotor assembly</u>: The rotor assembly consists of a stack of laminations of high quality electrical steel, which is filled with a conducting material such as aluminium or copper. In the case of aluminium, molten metal is forced into the slots of the stack of laminations in a die casting machine, and in the case of copper, suitable long sections of the metal are hammered into the slots.

Die-casting is an expensive operation and requires considerable care. For changing the moulds for different sizes, the time required is of the order of a few hours, as the whole cavity has to cool before removing the mould and fitting in a new one. There are two basic varieties of die-casting machines, a horizontal one for mass quantities and a vertical one where change over is quicker.

The primary rotating element is the shaft, which is made of high-grade steel. Machining of the shaft to the required sections, and milling of the keyhole are precision but standard operations. The die-cast rotor assembly is shrink fitted on to the machined shaft and the external surface is machined.

<u>Stator assembly</u>: In most motors, the inner assembly is the rotating one and the outer one is the stationary one, called the stator assembly. The stator assembly is made of laminations matching the rotor sections. The conducting material in this case is copper wire, which is wound in the cavities of the lamination. The precise control of the number of turns, the polarity and the connections of the winding is critical for the

electrical and magnetic properties of the motor. The stator assembly is also immersed in varnish and heat treated, for better properties.

End shields and other supports: There are a number of other cast components which have to be machined to support and enclose the motor assembly from either side. These follow the same type of operations as the housing. The end shields are circular and there are other castings such as the terminal box and base plate, which are of other shapes.

Assembly: The assembly operation for motors involves putting the rotor assembly inside the stator assembly, fixing bearings to the shaft, adding the endshield covers and attaching the electrical connections and installation elements. A fan and fan cover for cooling the housing is also attached.

Painting, testing and packing: These are routine operations, although the testing operation can be quite rigorous and lengthy depending on the type of performance features demanded of the motor. A trend worldwide is that painting quality for anticorrosion and other properties, and packing, especially for withstanding transportation damages is becoming more and more of a process concern.

In all these activities, it is the rotor assembly and the winding that require the real technical competence as the electrical properties which have been designed have to be obtained through the manufacturing process. Here is where the design, manufacturing and quality interface is the most important.

Some worldwide technological developments in Induction motor design and manufacture that IEML needs to track are as follows:

1) Automatic winding machines which give better quality are available, but they require quantities which are much higher than IEML is making to be really economical. The quantities need not be in very large batches.

2) Aluminium is emerging as a viable alternative material for the housing manufacture. This can be directly cast in the required shape and virtually eliminates machining. So far, the process is viable in the smaller sizes.

3) Die casting machines are being designed for quick changeover. For example, the veritcal machines provide for different core lengths to be produced with the same die.

4) Power electronics, permanent magnet motors and switched reluctance motors are newer options for the conventional induction motors. Power electronics, in particular, is important to incorporate into product design for better control, energy efficiency and maintenance ease.

5) Special steels with superior metallurgical and electrical properties is an ongoing research development, and this area is one which IEML has also invested some resources.

Indian Electrical Motors itself has core motor manufacturing capabilities at other locations in many of these areas. Some broad details about some of these facilities are as follows:

E1- Mumbai (Thane): [1953] Makes 3 phase induction motors upto from 1-10 HP.

E2 - Mumbai (Thane): [1956] Makes large induction motors above 330 HP. These are mainly made to order.

E3 - Kolhapur: [1960] Fractional Horse-Power (FHP) motors

E4 – Pune: [1981]   Mid-range 3 phase induction motors (10-300 HP), alternators, variable speed drives, and a few DC machines.

E5 – Madurai: [1990] Makes small single-phase FHP induction motors for dedicated customers.

E6 – Indore (proposed) [1998] Railway traction motors

The motors Business group has six other manufacturing locations and joint ventures all over India and one in Malaysia.

Questions:

0) What elements of the corporate and business/competitive strategy would be relevant in formulating and implementing manufacturing strategy? In particular, is the manufacturing strategy aligned towards the major competitive strategy focus for the Business Group and IEML as a whole? Would you say manufacturing as a function has played a proactive role or a reactive role in overall strategy formulation?

1) What is the basic manufacturing strategy with respect to make or buy? What manufacturing, if any, should be planned in house? If you were to estimate supplier strengths in this area of manufacture, what would you look for?   How important is a local vendor base?

2) What is a reasonable plan for capacity of such a facility, including outsourcing options? Indicate how would you normalise the concept of capacity for multiproduct operations as in this case?

Is the argument of economies of scale relevant in this case?

3) What would be the basic orientation of the manufacturing facility? Evaluate different options ranging from a completely product oriented layout to a process oriented layout.

In the case of a product oriented layout, what products would you group together to achieve this orientation? Where would you need to selectively deviate from this product based orientation?

In the case of process oriented layout, what would be a logical arrangement of processes, relative to each other?   What considerations would be relevant here?

How would you ensure flexibility of the manufacturing arrangement?

4) It is expected that the order books for the new plant will consist of the following mix:

80 percent of the orders will be long term stable orders for standard machines of known rating, size and dimensions and orders are known between six and eight months in advance. These are for orders from the Indian Railways. Despite the relatively high capital intensity of this equipment from the customer¹s viewpoint, there is some amount of seasonality in this over the year, to do with the financial and accounting year cycle.   The pattern is as follows:

In 1998-99 and 1999-2000, the Railways have committed to buy 18 units of 500 HP, two each in the first six months of the financial year and one each in the second half of each year, with upto 4 more per year, depending on the need.   These are subject to quality and performance tests at the time of order acceptance and the price has been pre-negotiated as per a contract.   The market inflation of prices of major inputs has been factored in.

In addition, 6 more orders (export) can be expected through marketing efforts in a year. These will typically be customised. Spare capacity, if any can be used for any refurbishing, retrofitting, maintenance etc.

What type of manufacturing management system is appropriate for this mix? Is this consistent with the facility plan?

5) What is the human resource policy for this manufacturing set up? The key point is to see how much the manufacturing strategy affects and is affected by concerns in this area. In particular, how would targets and norms be set for the volumes envisaged?

6) Assume that the following technical functions are required, in whichever way they are organised. Design, technical support, marketing and service support, process engineering, IT support for manufacturing, materials procurement and vendor management, quality, maintenance, manufacturing planning and control and methods improvement.

How would you like to organise these functions in tune with your manufacturing strategy? Once functional groups are organised in whichever way, what cross functional interactions are envisaged?

7) There are a number of parameters which measure the performance of a manufacturing system. They include:
a) length of delivery cycle
b) superior product quality and reliability
c) dependability of delivery promises
d) ability to produce new products quickly
e) flexibility to adjust to volume changes
f) low investment and hence higher return on investment
g) low cost.

Which of these need to be effectively measured and controlled? Which are the ones which the factory needs to be particularly good at, at this time? What is the role, then, of the other parameters?

8) It is expected that once the system stabilises, cost control and techniques such as Activity Based Costing would be important management initiatives. Is there any correlation between major cost drivers and the logic for facility and operations planning? For a start, what would you recommend regarding the allocation of overheads and indirect costs in this manufacturing facility?

n) A large part of the technical and managerial competence for this plant is expected to be provided by other divisions and plants of IEML. It is felt that the appropriate manufacturing strategy can evolve suitably, based on the strengths of the organisation. What directions would you give this line of thought?

n+1) Do you see any major impact of technological changes, and improvements to affect your manufacturing strategy? Would you say your strategy is geared towards meeting the challenge of technological competitiveness? What major technological changes are likely to affect the manufacturing strategy?

n+2) How would you estimate the suitability of Indore as a location for the new plant?

n+3) Because of various uncertainties, the plan of manufacturing at Indore has to be temporarily shelved, but committed orders have to be met. The E2 division at Mumbai decides to make a proposal for transferring the manufacturing at its site. What would be the major elements of manufacturing strategy in this changed scenario?

Exhibit 1: Product structure of a motor

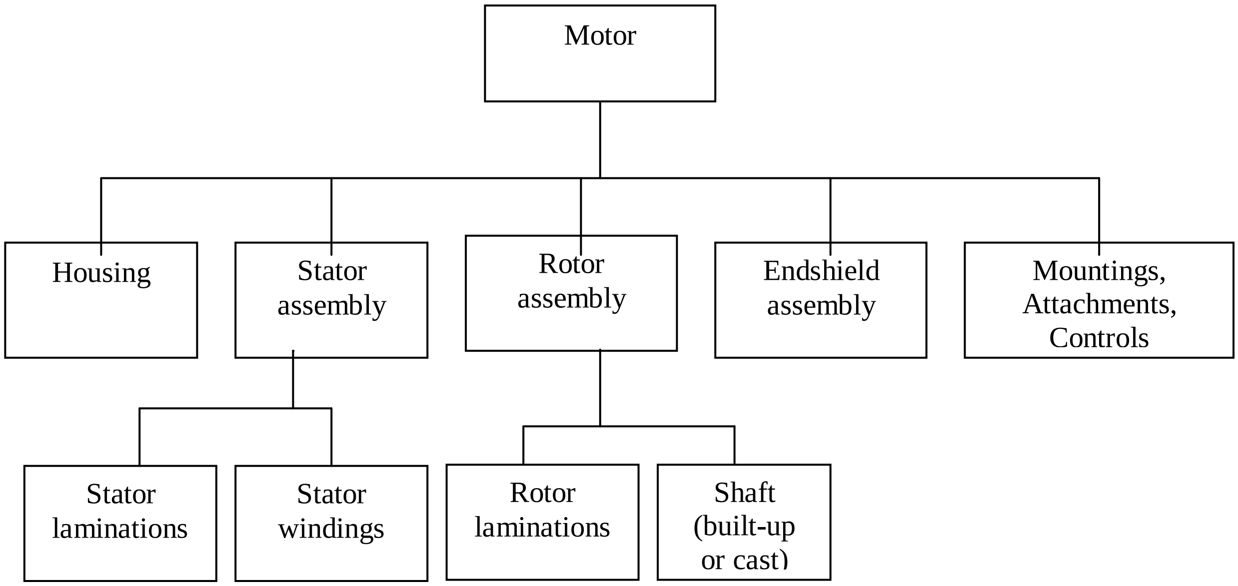
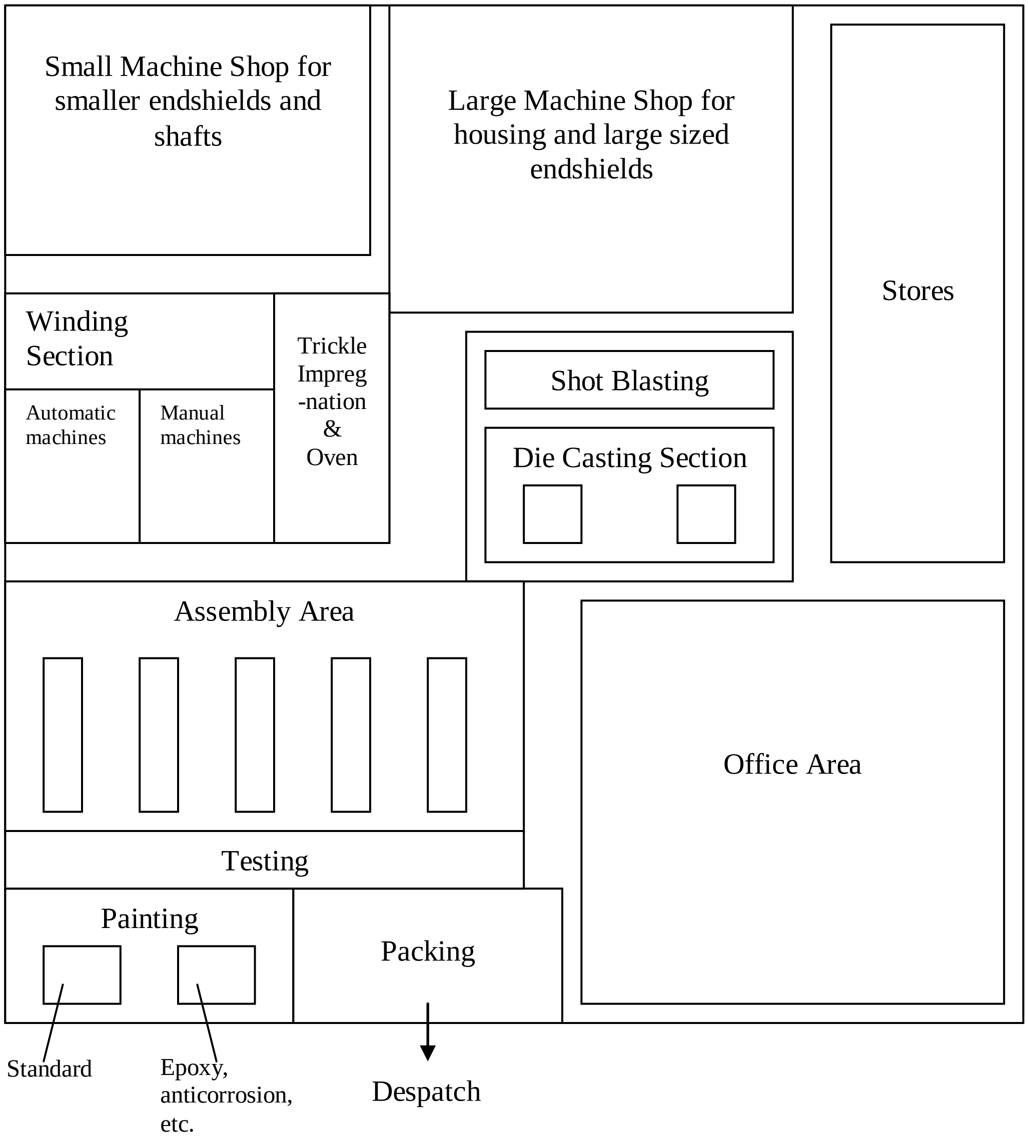


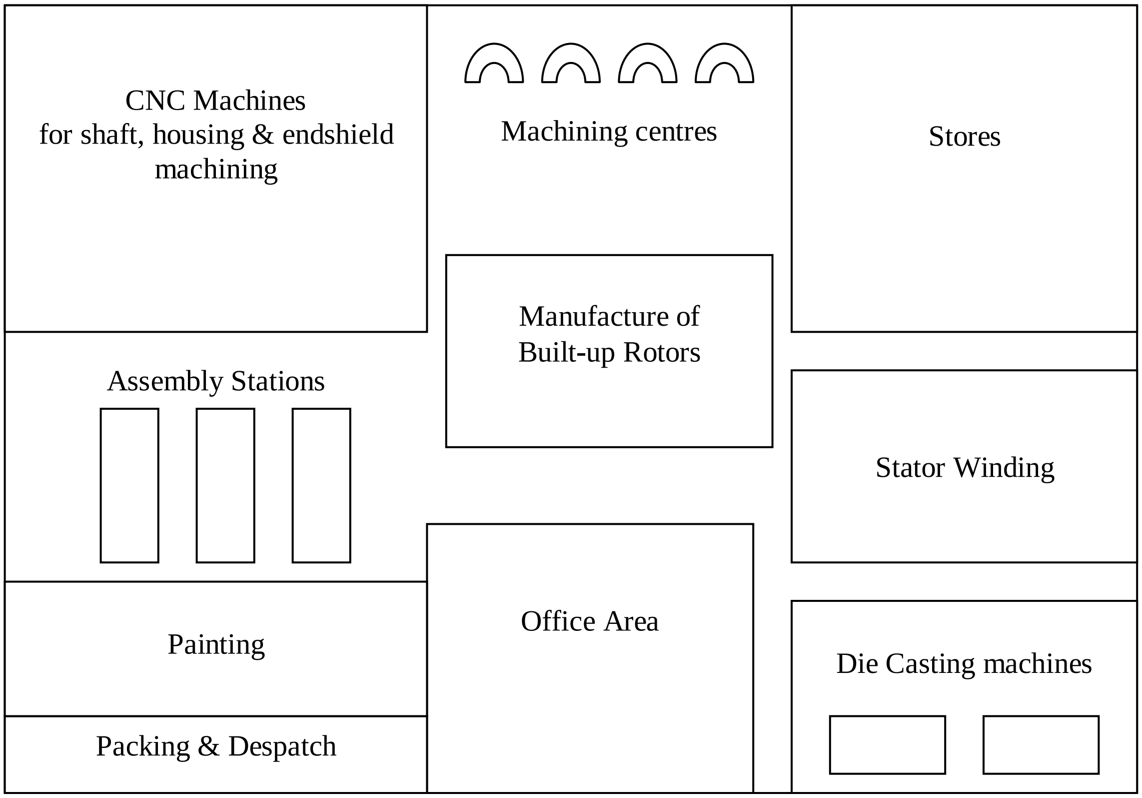
Exhibit 2: Layout of Plant E1



Features of Plant E1:

Turnover: Rs. 50 crores per annum
Product range: 10 to 330 HP
8 frame sizes – 56, 63, 71, 80 (outsourced); 90, 100, 112, 132 (inhouse)
15 varieties of stator body and endshields
Machines: Multicentre Special Purpose machines
Set-up times: 1 shift
Batch size: 200 to 600
Shafts are manufactured on two lines that are completely interchangeable
Planning system: Most products are made to stock, and planning is done based on quarterly forecasts from the marketing organisation. Machine loading is done on simple lot sizing principles (to avoid too many set ups). Material is procured according to an MRP system which assumes processing lead times based on experience.

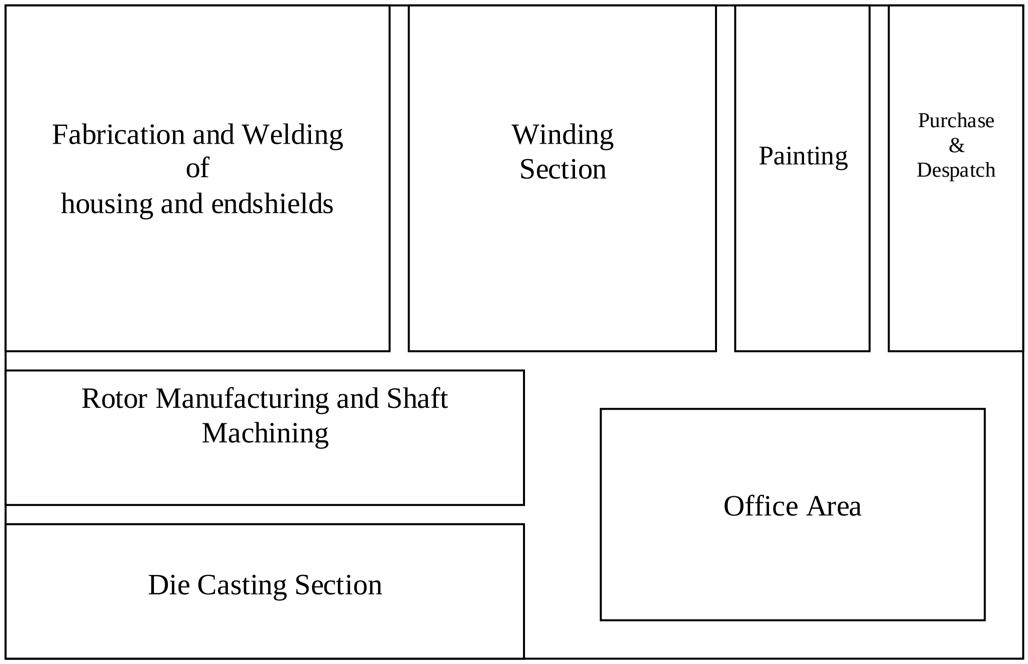
Exhibit 3: Layout of Plant E2



Features of Plant E2:

Turnover:	Rs. 45 crores per annum
Range:	350 HP and above
Order quantity:	Typically 2 to 20 units Many one off orders
Set-up:	Large set-up and changeover times
Planning system:	Each product is treated more or less like an engineering project. The critical operations are identified on bottleneck facilities, and operations are scheduled backward from there using the MRP logic. Usually, the winding facility is the bottleneck for this plant, because of old machines, imperfect work, extensive testing and frequent rework. Operations ahead of the bottleneck are usually driven by customer focused expediting (i.e. jobs are done as per urgency and customer queries about progress).

Exhibit 4: Layout of Plant E3



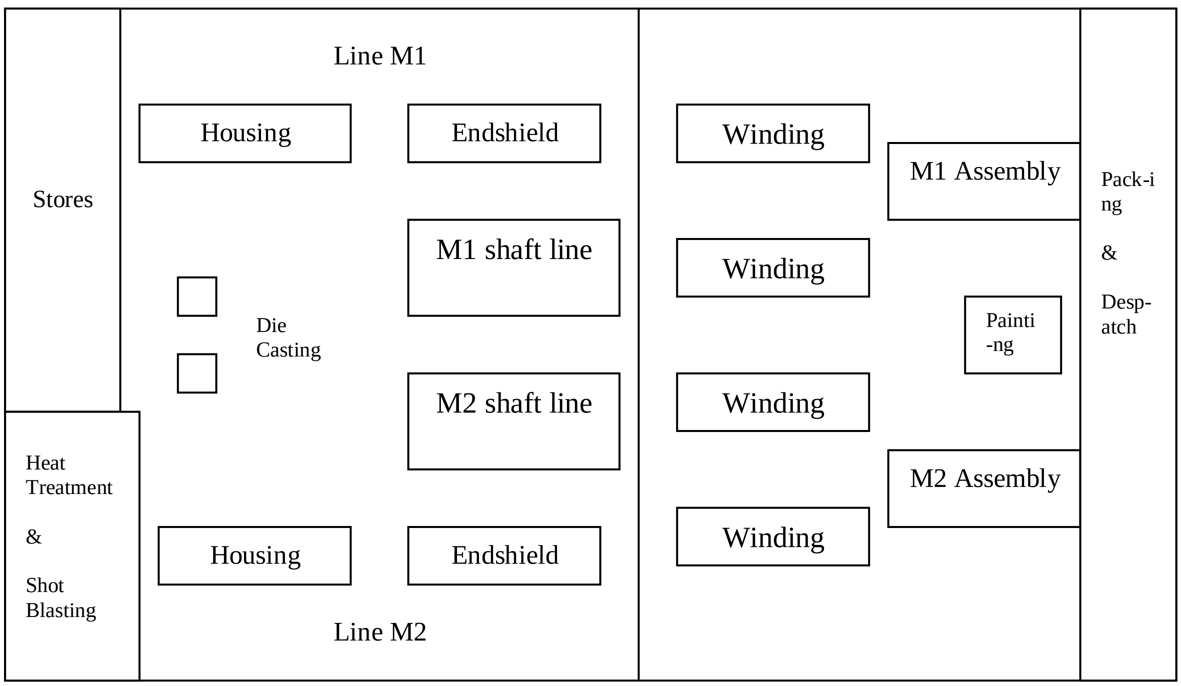
Features of Plant E3:

Turnover:	Rs. 40 crores per annum
Product Variety:	Very large product variety for applications like refrigerators, motors for small fans (e.g. Railway coach fans), grinders, mixers, Kitchen appliances, small drills tools, etc. These motors are mostly made for OEMs (75%) and for replacement and spares market (25%)
Batch size:	100 to 200

There is significant amount of outsourcing of almost all the operations in this plant. The company has decided to have at least some facilities for all the operations to improve reliability and also to be able to monitor vendor processes more closely.

Planning system: Order batches are taken up periodically (i.e. not all products are made in all planning periods). The most commonly demanded products are made in almost all weeks, and some occasionally demanded products are scheduled once in two months. Some capacity buffer is left in each week for making some urgent orders for some preferred customers. The attempt is to have one batch of orders flowing through the shop at any given time, but this does not always work out, because of unreliable component supply from vendors.

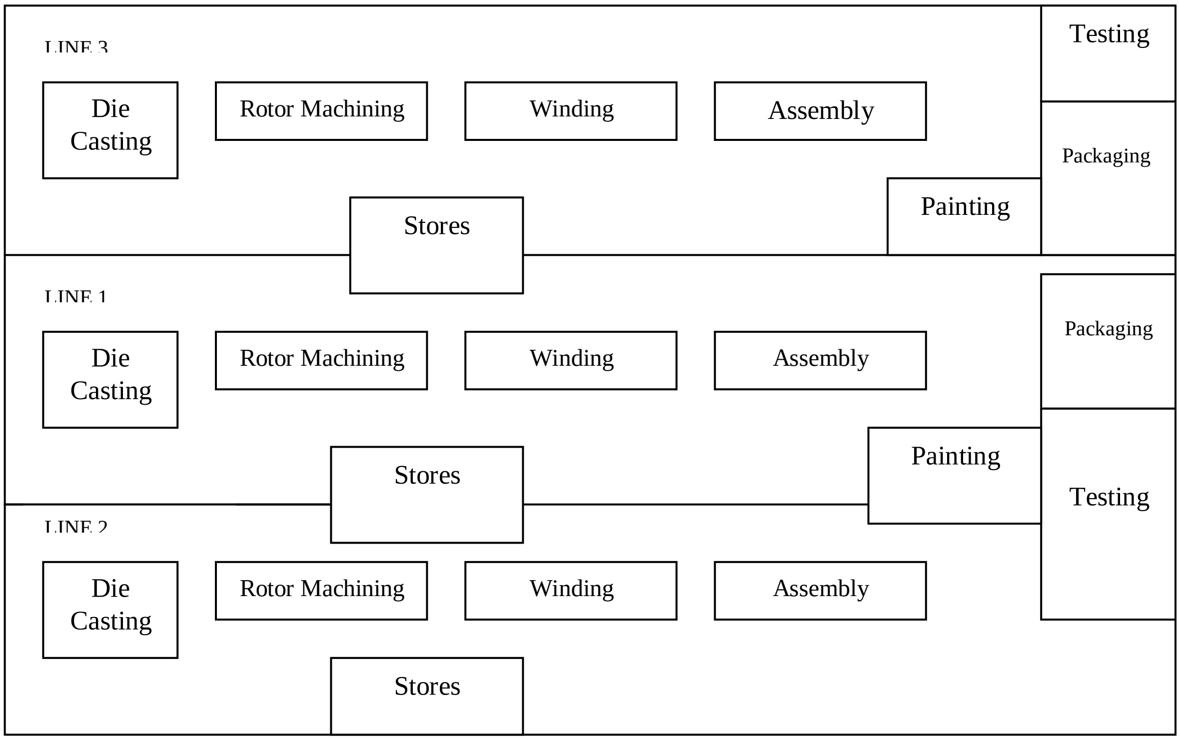
Exhibit 5: Layout of Plant E4



Features of Plant E4:

Turnover:	75 crores per annum
Range:	M1 – 10 to 30 HP; Capacity : 1600 units per month M2 – 30 to 330 HP; Capacity : 600 units per month
Order size:	Typically 4 to 5 motors
Set-up:	Set-up on all lines is 1 to 2 hrs
Customers:	M1 – 25% to regular customers (standard motors), 50% to dealers, (made to stock), 25% customized to needs of specific customers M2 – Almost all orders are customized (80% to regular customers, 20% to occasional customers)
Planning system:	The standard motors in line M1 are made according to a forecast. The WIP is controlled by having the machine loading at various stages driven by the winding schedule. The assembly stations handle the bulk of the customisation and accessories, even though it occasionally means some extra waiting and rework. On line M2, the products are driven by customer orders and due dates rather than forecasts. Ideally speaking, the assembly schedule due date drives the rest of the line, but because of time consuming set ups at some machines, there is batching in excess of the actual requirements.

Exhibit 6: Layout of Plant E5



Features of Plant E5:

Turnover: Rs. 30 crores per annum

Range: FHP (Fractional HP) motors

Lines 1 & 2 make about 20 different varieties for 12 customers (order batch size is typically 500)

Line 3 is dedicated to make 2 varieties for one customer (batch size is typically 1000-2000)

Other features: Endshields, housings, etc are outsourced

Planning system: The flow of products on line 3 is very smooth and predictable because of committed orders from a large customer. Here, the big issue is to maintain product quality according to very stringent customer specifications. The line is issued material according to the period plan, but the internal flow of material (and therefore machine loading) is according to a pull principle where consumption of items downstream drives the system.

For lines 1 and 2, the planning is done on a periodic basis, where every major product group is scheduled every week. This is done in a way so as to minimise the line set up time. The plant manages to achieve the objective of having one major product category flowing through the line at a given time and WIP therefore is controlled.