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Operations MOOCs

Operations management (Politecnico di Milano)

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INTRODUCTION TO THE COURSE

In this course we will focus on the main concepts of operations management.
In particular, we will tackle three main topics: the layout of the supply chain, the planning of the supply chain and the internal and external performances, which, as you can see from the picture, can be considered as the output of the first two ones.
Let's start focusing on the supply chain layout: we will see the main typologies of production systems, and the main typologies of distribution systems.
We will then analyse the performances of a company related to the production and logistics systems.
We will assume both an external perspective, thus dealing with the customer service, and an internal perspective, considering instead the logistics and production costs as well as the productivity.
In particular, for the customer service, we will see:
The definition of the main performances, and indicators and tools to measure them.
For the logistics and production costs, we will analyse the main cost items, which are:
Set-up costs, Transport costs,
Handling costs, Inventory carrying costs and
Stock-out costs.
For what supply chain planning is concerned, four main points will be tackled during the course: First, demand forecasting.
We will go through the demand forecasting process and we will see the forecasting models based on the analysis of the time series.
Second, stock management.
In particular, we will see the typologies of inventories and the main models to manage them.
Third, production planning.
We will deepen the principles of production planning and the models to deal with aggregated production.
Fourth, we will examine the materials planning, focusing on a specific technique, the materials, requirement, planning.
At the end of this course, by gaining knowledge about the three main macro-themes we have just presented, you will thus be able to understand and properly take the main decisions about both production and logistics systems.

MANAGEMENT OF PRODUCTION AND LOGISTICS SYSTEMS: BASIC

In this lecture we are going to introduce some basic concepts about production and logistics management.
More specifically, we will analyse: - the order;
- the codes to identify the products; - and the bill of materials.
First, let's focus on what an order is.
The order is a document that indicates the intention to buy some products and/or services.
Therefore, it is issued by the customer to the supplier.
The supplier usually sends back an order confirmation, in order to let the customer know that he properly received the order.
The order is identified by an alpha-numerical code, and and its main elements are:
The list of products that are required by the customer, which is the "core" part of the order.

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More specifically, the order is organised in several lines.
Every line is devoted to a specific item, and it reports the product code, its description and the ordered quantity. Then, at the top of the order we usually have the information regarding the customer and the supplier, which are essential for the invoicing process (the address, the headquarter, and so on).
Then we have the delivery terms, for example the maximum number of days to receive the products, or the specific day/hour in which the products will be received by the customer.
Then we have the place of delivery; And the method of payment that will be used, together with the terms of payment (e.g. 30 days after having received the invoice).
Now, let’s focus on the codes that are used to identify the products along the supply chain.
These codes can be used to identify pallet loads, cases, and single items.
According to the specific needs, we can have unique codes or not.
For example, in the fast moving consumer goods, all the pieces of a specific product (for instance, a box of 1 kg of spaghetti of a specific company) have the same code, whereas in other industries it can be interesting to be able to track and trace individual products, which are provided with a unique code (for instance, luxury goods).
Most of the products are identified using the standards proposed by GS1, the Global Standard Organisation.
Different technologies can be used to read the product codes, and they differ in terms of level of automation.
We can have: alphanumerical codes, which are usually read by a human, with no automation;
barcodes, which can be scanned one by one by humans or fixed readers (for example, on a conveyor);
and RFID tags, which are based on Radio Frequency Indentification.
In this case, the level of automation can be higher, since we can read hundreds of codes at the same time.
In fact, thanks to the use of radio waves, we can read all the tags that are sufficiently near to the reader.
The distance depends on the type of tags and on the materials (since – for example – the reading performance can decrease in presence of water or metal).
The codes have to satisfy some requirements.
Specifically:
The complexity of the codes must fit the needs of the company: for example a small artisan will have simpler codes with respect to a multinational company. Moreover, the codes must be compliant with national and international standards.
Let’s now consider the bill of materials.
This is a structured and hierarchical representation of all the different parts that compose the product.
More specifically, it is very useful since it allows to see:
How the raw materials and components are combined in order to have the final product;
And the use of the resources, since there are coefficients that indicate the quantities of raw materials and components that are required to make a single unit of the final product.
In order to better understand how to define a bill of materials, let’s see a simple example.
Our final product is a cheesburger, and we want to represent its bill of materials, in order to provide all the information needed to “assemble” the product.

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At the level zero of the bill of materials there is the final product, so our cheeseburger.
At the first level there are all the parts that compose the cheesburger, and that should be assemble together, so bread, cooked meat, cucumber, onion rings, ketchup, and cheese.
The numbers in the picture indicate how many components we need to assemble a cheeseburger, for example we need 2 slices of bread, 1 slice of cooked meat, and so on.
At the first level of the bill of materials we can have simple components (e.g. the slices of bread), or we can have components that require production activities that should be performed before the final assembly.
For example, if we consider the cooked meat, we have to consider that in order to have 1 slice of cooked meat we need to have a slice of shaped meat to be cooked.This is the level 2 of the considered bill of materials.
Moreover, in order to have 1 slice of shaped meat, we need 100 grams of minced meat.
We have just considered a very simple example, useful to understand the concept of the bill of materials.
Nevertheless, products are usually much more complex than a cheesburger, and as a consequence also their bill of materials is becomes more complex, and more useful.
For example, imagine that you have to define the bill of materials of the engine in the picture.
You would have much more components, organised in numerous levels.
In this lecture we have seen some basic concepts related to production and logistics systems: the order, the product codes and the bill of materials.
All these concepts will be useful to better understand the contents that will be illustrated in the following lectures.

PRODUCTION SYSTEMS: TAXONOMY

In this lecture, we are going to have an overview of the main typologies of production systems.
Production systems are intended to turn raw materials into finished products.
They can be classified based on three dimensions.
First, how we meet customer demand.
The choice depends on the lead times:
if the delivery lead time required by the customers
is lower than the manufacturing lead time (i.e. the time required to make the products),
the manufacturer must produce before receiving the orders,
otherwise he can decide whether to produce before or after receiving the orders.
More in detail, the decoupling point separates the production phases
performed before receiving the order from those carried out after.
Based on the decoupling point, we can distinguish five types of production systems:
In a make-to-stock production system, the goods are made and stored before customer orders are received.
It is therefore crucial to be able to forecast customer demand,
in order to prevent stock-outs (that lead to poor customer service)
or extra-stocks (that lead to high inventory holding costs for the company).
Make-to-order systems are largely adopted for examples in the fast-moving-consumer-goods industry
(to produce packaged food, detergents, etc…)
In an assemble-to-order production system,

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a number of standard modules are pre-assembled and stored.
Then, after receiving the orders they are combined together to make the finished products.
Assemble-to-order systems are very diffused in the automotive industry.
In a make-to-order production system, the products are made from raw materials and components after receiving the customer orders.
Make-to-order systems are adopted for example in the furniture industry,
or for producing top-level cars.
A purchase-to-order production system is similar to a make-to-order one,
but also the raw materials are bought after receiving the customer orders.
The only activity that has already been performed by the company is the product design and engineering.
For example, purchase-to-order systems are adopted for small boats.
In an engineer-to-order production system
the company works with the customer to design and then make the product.
Engineer-to-order systems are adopted for example to make new buildings, plants,
large boats and airplanes.
Production systems can also be classified based on how the production process is organised.
We can have three solutions:
Continuous production: the production system
is devoted to just one product that is usually produced 24 hours per day, without stops.
Some examples are the production of paper, glass, and mineral water;
Batch production:
different products are manufactured in the same system.
Batches consist in groups of the same item
(e.g., we produce 50 units of product A, then 100 units of product B, and so on).
Single piece production:
every product differs from the previous one.
This can be due to the fact that the company makes unique products, strongly customised
(e.g. airplanes).
Moreover, production systems can also be classified based on how the products are made.
More specifically, we can distinguish among: process production,
in which the products undergo physical-chemical transformations that are not reversible.
Therefore, the original raw materials can't be obtained back from the final products.
Some examples are the production of paper, glass, fabric, and cakes;
then we have part production
(also referred to as manufacturing production),
which comprises fabrication and assembly.
Fabrication is intended to produce components and parts
that are then assembled to obtain the finished products.
During fabrication, irreversible physical and morphological transformations are performed,
but the original raw materials can usually be recognised in the finished products.
Some examples are the production of home appliances, personal computers, and cars.
In order to perform the fabrication phase,
the production plant can be organised according to different layouts.
The main solutions are job-shops and transfer lines.
Job shops are manufacturing systems organised in different work centres.
In every work centre we can find machines that can perform similar activities
(e.g. turning, milling, hobbing, …).

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Each product has its own routing, that defines a route through several types of machines.
Usually, there are alternative routes.
The management of production flows is therefore quite complex,
and products spend most of the time waiting in queues, leading to high work-in-progress.
As a result, the throughput time is significantly higher than the total time spent on the machines.
Despite these limitations, job shops have some advantages.
They are usually very flexible, and can produce a large mix of items.
Moreover, the capital expenditure to set-up a job-shops system is quite limited,
if compared to other solutions.
In production lines machines are arranged in stations that are put in a sequential line,
and each product passes in each station.
A line is dedicated to the production of a single product, or a product family (i.e. similar products).
Production rates are extremely high, the work-in-progress is very limited,
but the solution is not flexible and the system is strongly impacted by failures.
A failure in a specific station usually stops all the production line.
Moreover, to properly design a production line is quite difficult,
since the cycle time of the stations
(i.e. the time to perform the required activities) should be very similar.
As for the assembly phase, we can have three main solutions:
fixed position, assembly shops, and assembly lines.
In the fixed position assembly, the product does not move,
while components, tools and workers converge on the assembly-site.
This solution is suitable for assembling big and heavy objects,
like aircrafts and boats, produced in small volumes.
The assembly shops are similar to job shops,
since the products move through several assembly centres with different routings.
They can be used to assemble a mix of similar products in small-medium volumes,
for examples top-level cars.
In assembly lines, all the products go through the same stations.
In each station a specific set of activities is performed.
Based on the type of transport between the stations, we can distinguish:
fixed transfer systems,
in which the products move from one station to another at fixed times, using a line belt;
not constrained transfer systems,
in which there are small buffers (containing work-in-progress) between the stations;
continuous transfer systems,
in which the products slowly move through the stations, without stopping.
The workers carry out the required operations while the product is moving.
This solution is quite common in the automotive industry.
In this lesson we have seen how to classify production systems according to:
how to meet customer demand; how to make the products;
how to organise the production process.

DISTRIBUTION SYSTEMS: TAXONOMY (PART 1)

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In the previous lecture we have seen the taxonomy of production systems.
In this lecture we will instead analyse the one of distribution systems.
First of all, let's understand what a distribution system is.
A distribution system is made by all the inter-company and extra-company resources and structures involved
in the transport and sale of the goods, and the associated services to the end customers.
A distribution system is made by:
the logistic channel, that allows the flow of both products and information
from the manufacturer to the final consumer;
the trade channel, that is aimed at transferring the property of goods
from the manufacturer to the final consumer.
Focusing on the logistic channel, it includes:
the distribution network, whose nodes are plants, warehouses and points of sale;
and the transport systems that connect the nodes of the network.
The logistic channel has four main functions:
first, consolidation, sorting and transport optimisation,
allowing the collection of large lots from upstream and the preparation of the materials
that are required downstream;
second, product mixing, to gather all the different product lines manufactured in different plants;
third, the increase of customer service, allowing the reduction of the order cycle time
and the increase of the order cycle time reliability.
Focusing on the nodes, and in particular on the warehouses,
they may be classified either according to their location within the supply chain or according to their function.
Based on their location, it is possible to distinguish between:
plant warehouses (in which raw materials, semifinished products and interoperational stocks are stored)
and network warehouses (which are warehouses containing finished products,
transit points and distibution centers).
Based on their function, it is possible to make a distinction between warehouses and transit points.
In warehouses orders from downstream are fulfilled by using inventories.
Upstream orders aim at replenishing the inventories in the warehouse.
In transit points orders from downstream are sent straight to upstream.
Orders are fulfilled upstream, but they are delivered and sorted through the transit point.
In a warehouse with inventories there are five main functional areas,
each one associated to a specific activity carried out within it.
They are: Receiving, in which carriers are scheduled,
vehicles are unloaded and products are analysed to identify eventual damages
and they are compared to the purchase orders.
Put-away, in which the storage locations of products are identified,
products are moved there and the related records are updated.
Storage, Picking, in which orders are managed,
goods are picked and moved, and packages are labelled.
Shipping, in which carriers are scheduled, vehicles are loaded, the bill of lading is prepared
and the related records are updated.
As for transit points, they adopt at least two different operative models:
First, only sorting of Transport Units which have been completely picked upstream.

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Second, receipt of a massive delivery, i.e. aggregation of different customer orders,
and the picking and consolidation of Transport Units for each customer.
Focusing on the arches of the logistics channel, and so on the transport,
there are four main transport modes that can be identified:
road, rail, water and air transport.
It is also possible to rely on the so called “intermodal transport”,
which combines different transport modes.
Considering road transport, there can be full truck load and less than truck load shipments.
In the full truck load option a semi-trailer, or a trailer,
is dedicated to a shipper who fills it with freight for one destination.
The shipment is usually picked up from one point of origin and delivered to one point of destination.
Full truck load is generally used for the primary transport.
The less than truck load option is used instead for the local distribution.
The transport means are usually a combination of small trucks/lorries
(for the pick-up and delivery)
and large trucks/articulated vehicles (for the line haul).
Let’s switch now to rail transport.
In the railroad traditional service, the carrier rents space on a train relying on different configurations:
first, a unit train,
where the shipper rents a whole train going from one point of origin to one point of destination.
It is similar, from the managerial point of view, to Full Truck Load road transport.
Second, a full car load.
Third, less than a car load, typically pallets or cases.
Rail is usually used to transport low-value goods for large quantities and long distances,
typically bulk raw materials, such as cereals or coal.
It should be considered that rail is a viable option when time performances,
both in terms of speed and reliability, are not critical.
For what the water transport is concerned,
there may be transoceanic or coasting shipments.
Transoceanic shipments are international and made by big ships,
while coasting and internal waterways refer to shipping goods for short-medium distances
between points on the same coast or along internal navigable waterways.
Water transport is used for commodities with a low value-to-weight relationship
or for which transport cost is a significant portion of the selling price.
In the end, let’s consider air transport.
There are two main options:
freight only, or passengers and freight,
if the plane is not completely dedicated to the shipment of goods.
Transport unit loads may be:
Specific containers aimed at maximising the loading capacity;
pallets
or bulking single products.
Air transport is used for long-distance shipments of high-value products
and/or when transit time is critical.
If we instead consider those cases in which different transport modes are combined,
it is possible to identify three main options:

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multimodal transport, in which at least two different transport modes are used;
intermodal transport, in which different transport modes are used,
but always moving the same unit of transport
(the so-called ITU – Intermodal Transport Unit, for example a container);
and combined transport, in which the main path is managed by rail or water
and the initial and final parts are instead managed by truck.

DISTRIBUTION SYSTEMS: TAXONOMY (PART 2)

After the transport modes, let's consider the taxonomy of the distribution network.
Distribution networks can be classified on the basis of two dimensions:
the number of echelons and the number and typology of warehouses in each echelon.
Let's start considering the number of echelons:
there can be direct shipping from the points of origins to the points of destinations.
More frequently, warehouses may be located between the point of origins and the point of destination.
In this case, we can have distribution network made of 1 echelon, 2 echelons or 3 or more echelons.
Considering instead the number and typology of warehouses in each echelon,
there can be warehouses with inventories or transit points.
Let's start considering the 1-echelon distribution network;
in this case, the central warehouses,
which could be 1 or more, fulfill all the assignments of the logistic channel.
Central warehouses have three main functions:
first, they ensure product mixing, if suppliers only focus on a small part of the product range.
Second, they face the trade-off between the order cycle time and the safety stocks.
Third, they optimise transport from plants to delivery points
(thanks to the reduction in the number of connections and the ensuing increase in trucks utilisation)
Let's now switch to a 2-echelon distribution network:
goods pass through two different levels of the distribution network
from the points of origin to the customers.
The second level of warehouses in a distribution network,
in which there are the regional warehouses,
provides the following supplementary functions:
it ensures an higher service level in terms of both cycle time and punctuality
(indeed, regional warehouses hold inventories facing the demand of a specific area).
And it optimises transport to end customers, i.e. the local distribution.
In some cases, instead of the regional warehouses we can have transit points.
Therefore the distribution network is made up of 1-echelon plus transit points,
and the goods pass through one "inventory echelon" and one transit echelon, with no inventories.
Transit points aim to optimise transport to the end customers
(which is the so called local distribution)
by accepting a longer cycle time, which is on average 1 or 2 days higher
than the one of a 1- echelon distribution network.
In this lecture we have seen:

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the definition of distribution systems and their main characteristics;
the main types of warehouses;
the main transport modes and different types of distribution networks.

PERFORMANCE MEASUREMENT

In this lecture we will see an overview of the main concepts related to the performance measurement of production and logistics systems.
The main objectives of performance measurement are the following ones:
- quantifying in an objective way the results of company processes and activities;
- promptly identifying anomalies, in order to correct them;
- monitoring the evolution of performances during time, while comparing them to the customer's needs and the objectives of the company; - providing incentives or penalties through the principles of the management by objectives.

There are different elements to be defined in order to create a performance measurement system.
Each element answers a question.
A set of indicators (which answers to the question WHAT).
The measure of the indicators (HOW). The frequency of the measurement (WHEN).
The targets with which the results of the measurement are compared (which TARGET).
The functions in charge of the measurement (WHO).
In order to better understand these concepts, let's see an example referred to their application in the e-grocery context.
Indicators to measure performances of the logistic system could be the punctuality, the delivery completeness and the order cycle time.
If we consider the punctuality, two examples of measures could be the percentage of orders on time, or the average delay per orders.
The frequency of the measurement could be, for example, one per week or one per month.
This choice depends on the trade-off between the amount of information and the costs.
The target could be set for example to 99% (of orders on time on the total delivered orders).
In the case of punctuality the person in charge could be the driver; if we instead consider accuracy, he could be the picker.
In order to work properly, a performance measurement system should respect some requirements.
Completeness: it has to consider all the factors that significantly impact performances;
Precision: it has to be able to detect even small variations of performances, representing them through variations in the value of the indicator;
Clarity: it has to provide results which are easily understandable by users;
Promptness: it has to provide results quickly, in order to be able to promptly apply eventual corrective actions; Responsibility focus: it has to consider performances whose responsibility is clearly associated to specific people or functions;
Limited costs: costs to collect data and analyse the results should be limited;
Long term orientation: the horizon considered should be medium-long, in order to provide a wider view of performances over time.
It is important to define how performances are measured, because this may have a double effect.

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A direct effect, since the way performances are measured may influence performances themselves.
For example, measuring the average delay of an activity may imply a higher number of activities with a low delay.
Measuring instead the number of delays may imply a low number of delayed activities, whose delay is though very high.
An indirect effect.
For example, measuring labour productivity may cause both overzealous and reluctant behaviours.
Performances may refer to two main dimensions, effectiveness and efficiency.
Effectiveness is intended as the capacity to achieve the objectives.
It consists in the ratio between the output and the target.
Efficiency is instead intended as the ratio between the value generated by the company and the value of the resources used for that aim.
Thus it is the ratio between the outputs and the inputs.
A company can be seen from a double perspective: as a customer from its suppliers and as a supplier from it customers.
Moreover, there are two types of customers a company has to consider, and for which its performances have to be measured: External customers, which are the real company's customers and Internal customers, which are functions
and departments which use as inputs the outputs of other upstream functions and departments of the company itself.
Consistently, it is possible to distinguish between internal and external performances.
Internal performances are those seen by the company and comprehend both effectiveness and efficiency ones (such as productivity and logistics costs).
External performances are the ones seen by the customers, and they correspond to the four marketing levers (Price, Promotion, Product and Customer service).
Let's now consider two elements of internal performances, logistics costs and productivity.
Logistics costs measure the costs of the resources (such as labour, transportation means, plants and energy) needed to "create" the output of the process.
The main logistics costs are: Transportation cost,
Handling cost, Cost of inventories,
Cost for quality and cost for poor quality, Set-up cost,
Cost for managing orders and the Cost of the stock outs.
Productivity is the ratio between the output (delivered products meeting the expectations in terms of product and service quality) and the input (production factors).
It may refer to different elements (such as labour productivity, energy productivity, material productivity…).
Switching now to external performances, let's consider the Product quality.
There are four dimensions that can be considered: The design quality, which expresses if the product design responds to customers' specifications; The conformance, which measures if the products
respects design requirements; The reliability, which is the ability of the product to keep its performances over time; The technical assistance, which is the ability of the system to ensure an effective technical support service for products.
In this lecture we have seen an overview about the performance measurement of a company.
In next lectures we will deepen some significant indicators that are used for the aim illustrated.

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