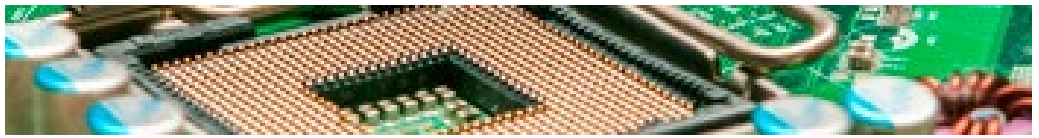
Unit 6

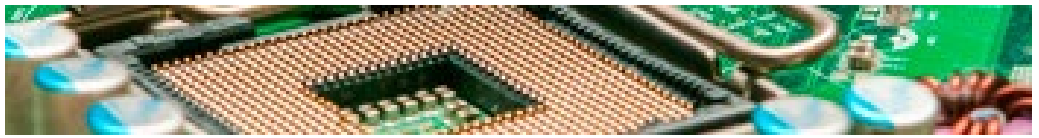
Path, route and distribution planning as optimisation problems

Optimización de problemas de distribución y rutas



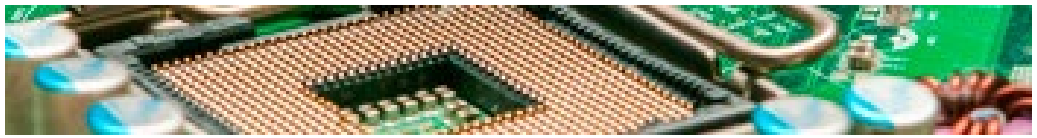
Contents Part 1

- Distributions problems and freight load/unload services
- Vehicle and path problems
- Route and timetable optimisation



Motivation

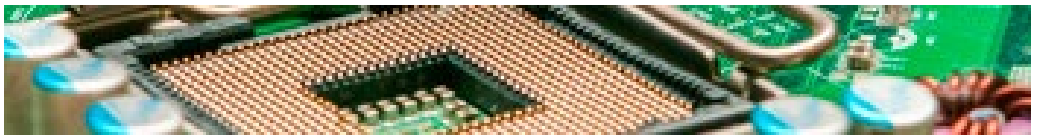
- Evolution and blowup of distribution tasks in organisations (e.g. e-commerce)
- Huge increase of complexity in shipping and distribution operations, mainly due to:
  - need to reduce production costs
  - increase of shipping prices (e.g. fuel and taxes)
  - increase of the customer-provider requirements (e.g. customer service guarantee, quality of service, service time, average cost, etc.)
- Logistics management as a **key factor** in industry strategy



The overall **goal** is to find out the shipping routes (including the path, load and unload operations) that lead to a highly successful customer service

Key elements:

- Transport network: nodes and edges
- Vehicle fleet, drivers and other crew: resources & timetables
- Storehouses and depots (central o distributed): inputs and outputs in the commerce flow
- Customers and providers and the services to support: supply and demand, and/or other intakes
- The **solution** routes, including paths and plans of variable granularity, always subject to the problem constraints



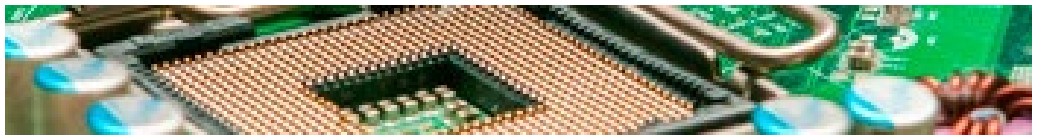
Route optimisation comprises all actions that contribute to the improvement of distribution, in terms of quality of service, quality enhancement, cost reduction, time, pollution and environmental impact, etc.

According to *Brain Trust Consulting Services*, there are 3 decision layers:

1. Strategic: how distribution is planned
2. Tactical: how operations are adjusted and tuned
3. Operational: how the day-to-day decisions are taken

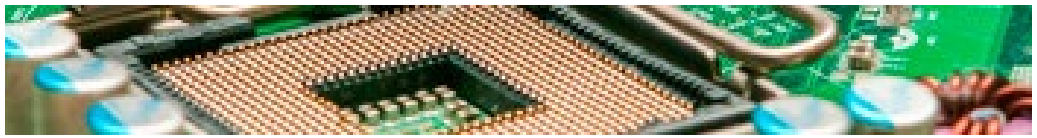
Optimisation routes comprises **necessarily the three decision layers**; however, it usually gives special emphasis on the more tactical and operational decisions

Libro Blanco de las TIC en el Sector Transporte y Logística



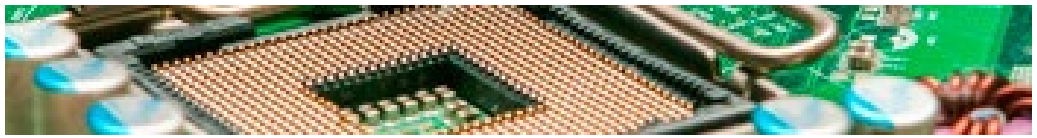
Clearly define the **optimisation goals**; that is, the scope of the problem to be solved and the variables that are involved through the optimisation process

- Do we need to improve the service quality (e.g. in terms of makespan), increase the robustness to delays, reduce the routing cost, etc.?
- In case of multiple goals: which are the priority goals? Do we need multiobjective optimisation?
- Which are the hard/soft constraints in our problem? How a new route can affect other already planned routes?



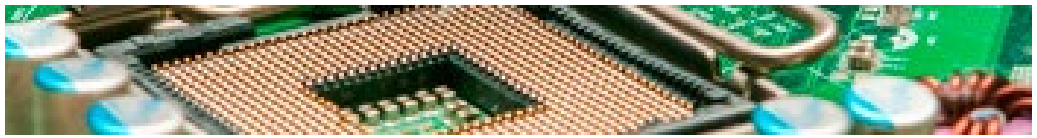
Clearly define the **current service** in terms of product/goods main features, routes and organisation

- Is that for short-, medium- or long-distance routes? Is it a radial or circular road system?
- Which is the available type of fleet: owned/outsourced fleet, exclusive/shared vehicles, etc.? Which is the cost?
- Which are the problem constraints in vehicles (physical such as volume and maximum permissible weight, and timetables)? And what about the freight (e.g. dangerous, store refrigerated goods)?
- Can we use the return shipping trips?



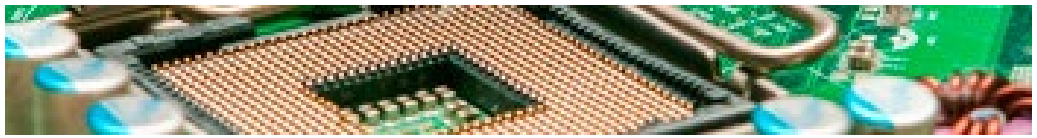
Clearly define the **current service** [...cont.]

- General constraints on delivering timetables, calendar and places – importance of working shifts, depots capacity and costs, and stopping costs of vehicles (waiting for service)
- Are there legal constraints/laws (rest periods and tachographs) for drivers?
- Which is the maintenance plan of vehicles?
- Which are the delivery priorities? Are there higher-priority or preferable routes (*soft vs. hard constraints*)?
- Are there automated systems to gather information to monitor the vehicles' state (*synchromodality*) in real time?



Clearly define the **expected result** of the optimisation process. Do we need a system than manages several routes (less flexibility) or one more flexible for fewer routes (more limited)?

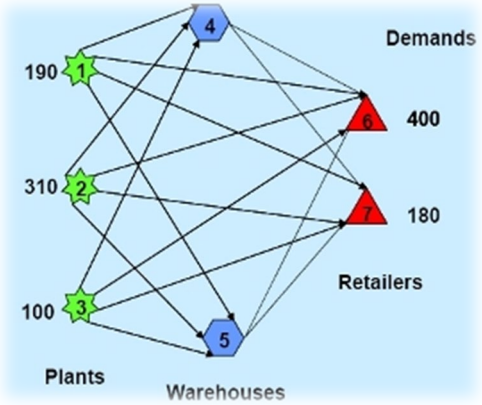
- Fully automated or hybrid (*Mixed Initiative Planning*)?
- Inputs/outputs integrated with other software/systems of the organisation?
- Type of information that is required as the optimisation process output?
- Optimality or satisfiability? Optimality is not always possible

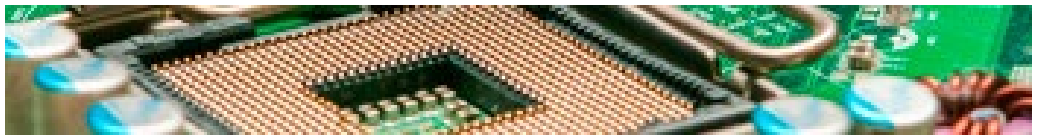


Route optimisation for distribution problems is **not easy**

- it involves many elements: vehicles, network, freight, supply and demand, resources – not all of them can be optimised simultaneously
- it entails 3 decision layers: strategic, tactical and operational
- it is a very time consuming process
- it is usually faced by techniques for network flows

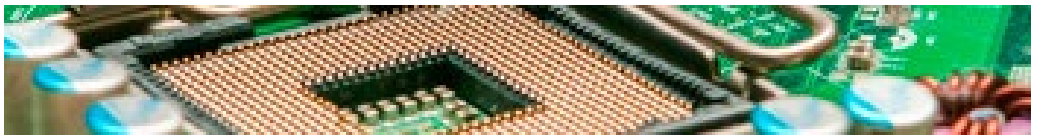
modelled as a graph





Contents Part 2

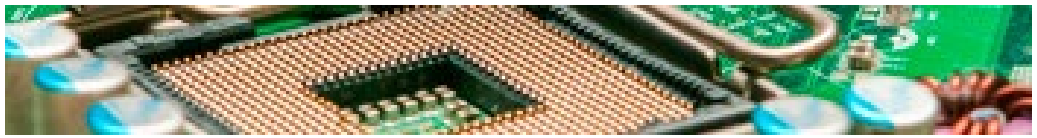
- Multimodal and intermodal transport
- New advances: synchromodal transport



Multimodal (or combined) **transport** is the type of freight shipping that combines **at least two** different transport modes, subject to **only one** transport contract

- The provider creates only **one contract** for the transport service; it's typically an outsourcing model

- Bulk freight can be shipped with or without (bulk) containers, or perform domestic multimodal transport
  - More complex model



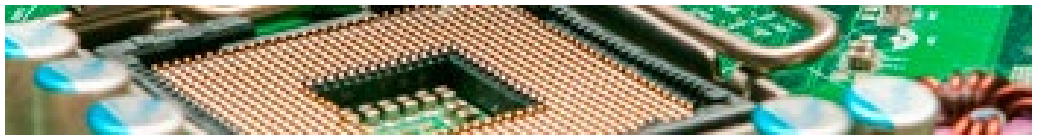
The **expected goals** are:

- Reduce costs and, consequently, increase benefit and competitiveness
- Reduce the environmental impact (CO_2 and *greener cities*)

"In 2010, EU-27 freight transport was close to 3.9 trillion tonne-kilometres (tkm), of which about 45% was on the road and 40% by sea. Currently, only 5% of internal EU freight traffic flows through intermodal routes. Eurostat surveys estimate that 24% of good vehicles in the EU are running empty and that the average loading of the rest is 57% giving an overall efficiency of 43%. Flow imbalance can only explain half of this loss.

The total volume of logistics expenditures in the EU was estimated at EUR 930 billion in 2010. A 10% to 30% improvement in efficiency in the EU logistics sector has been estimated to give savings of between EUR 100 billion and EUR 300 billion per year."

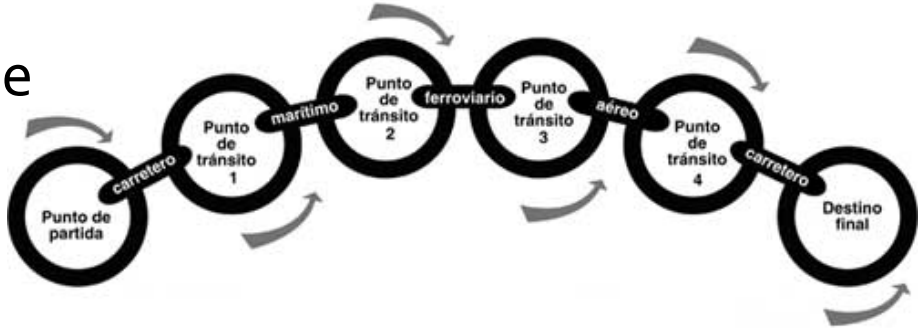
Section "6 Logistics" of work programme Horizon 2020

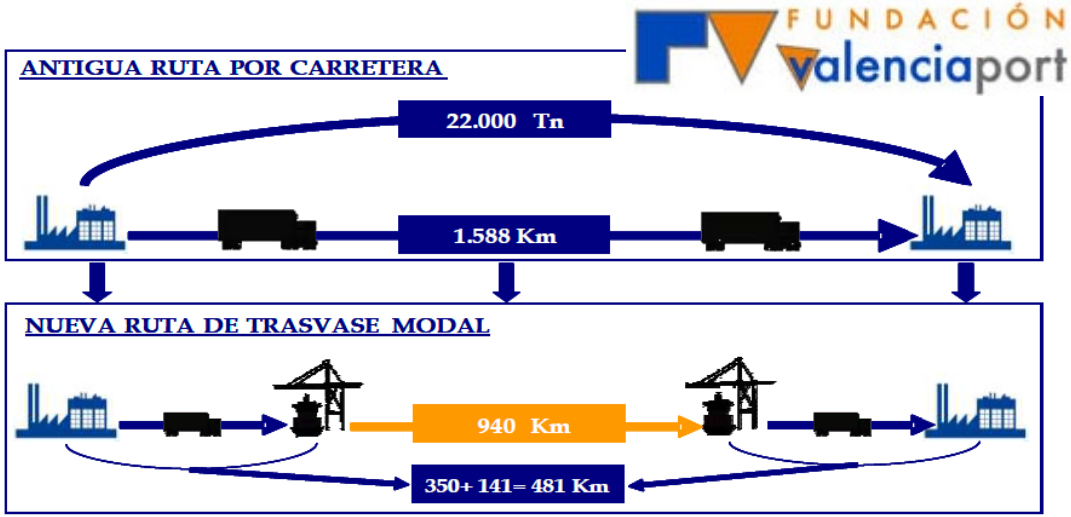


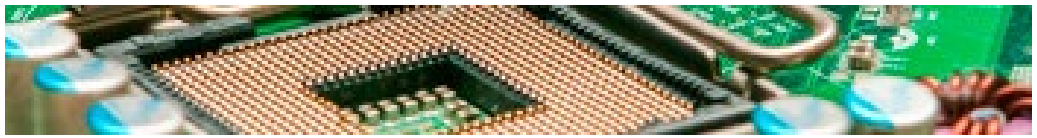
Main features

- There exists only one transport chain – the change of transport modes is **not** considered as different brokers
- We try to use transport modes with *higher* load capacities (in principle, this seems a smart decision)

Multimodal transport chain





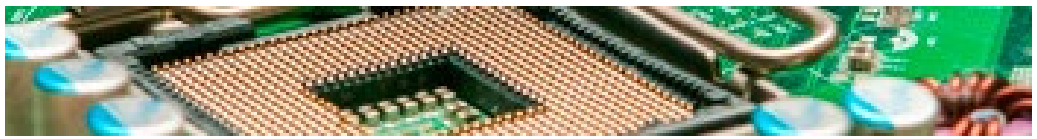


Advantages:

- According to experts, reduce the handling times – up to 70% in (un)loading operations
- Reduce the transport cost and delivery terms – use of the most adequate and reliable transport in every moment, thus decreasing traffic congestion
- Others: reduce the checking time for sealing and locking (some customs controls can be avoided), more simplicity in packing lists, better traceability, etc.

Disadvantages:

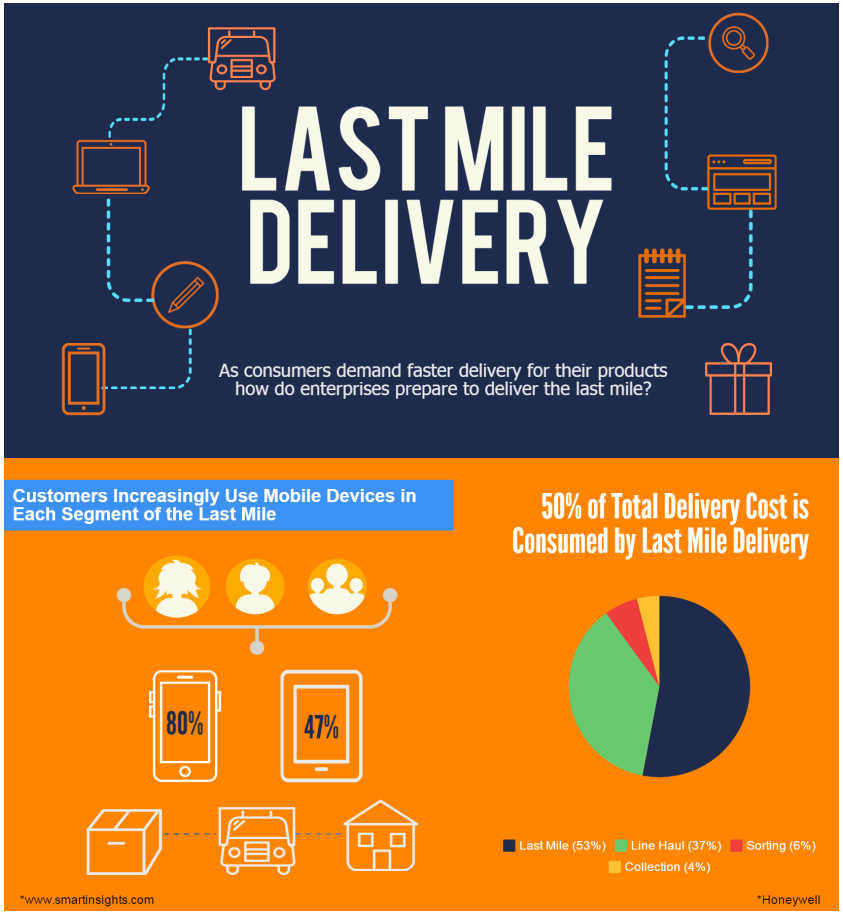
- Difficulty of transfers in locations with limited and low infrastructure
- Higher complexity to coordinate all the shippers that are involved
- No international regulation/law, which usually leads to norm conflicts

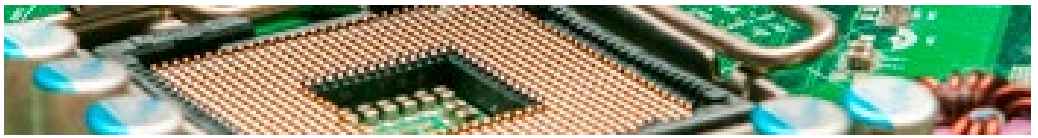


Intermodal transport is a multimodal system (at least two different transport modes are required) where **freight is grouped** in load units, mainly in containers – no handling of the freight when changing modes

- More agile (speed and effective) handling, load and unload operations
- Informally speaking: "*the shortest distance is done by using a small truck (**last mile logistics**), whereas the longest distance is done by rail or sea*"

Last mile logistics, the last leg of delivery, ending up at the consumer's home or business, has become a **real challenge**





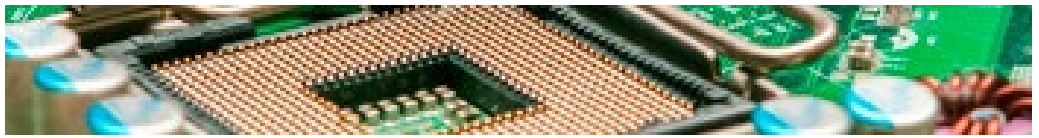
Some statistics about the last mile logistics/delivery:

- 16% of vehicle trips in cities are done by delivery vehicles
- 50% of fuel used in cities is for freight transportation
- 25% of CO_2 emissions are from freight transportation/delivery
- 80% of delivered parcels are below 30Kg
- 30%-50% of the total logistics costs are due to last mile logistics/delivery

Every little helps

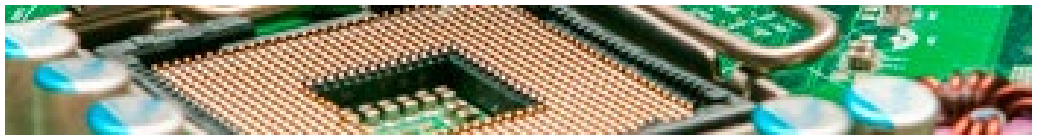
Synchromodal transport is the optimally flexible and sustainable deployment of different modes of transport in a network under the direction of a logistics service provider, so that the customer (shipper or forwarder) is offered an integrated solution for his/her (inland) transport

- To better understand the customers' needs
- To ensure the continuity of the transport flow; but it requires smart coordination mechanisms: use of infrastructure + technology + services + regulation policies
- To achieve a more flexible and efficient transport by freight consolidation (grouping)
  - probably a slower flow, but with a high load (occupation) flow
  - less energy is needed, which means less environmental impact



It is a transport mode that, by **using a plan of reservations** and **highly efficient management**, allows the user to make changes in decision taking (transport mode and paths) in real time, even when the trip has started

- Changing the transport mode at any time, in terms of the cost and environmental impact
- Dynamic planning that deals with unexpected circumstances (before or during the transport)
- Combining, consolidating and synchronising freight, thus taking advantage of the potential of network corridors via rail and ships (e.g. Mediterranean and Atlantic corridors)
- In other words, it is a **highly dynamic and easily exchangeable** mode of transport

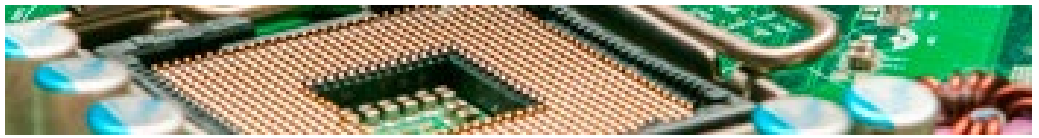


Advantages (via examples)

- Dockers in ports are on a strike? We change to road transport!
- Bad weather creates delays in sea transport? We change ports and make the transport by high-speed train networks!
- Like a rule: **if**… **then**…

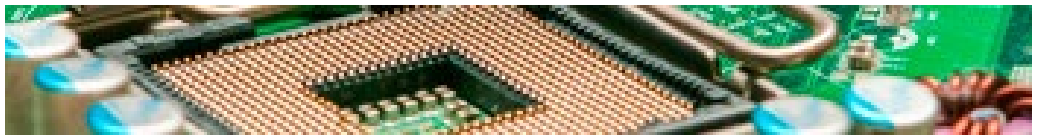
EUROPEAN GATEWAY SERVICES

"The best combination within the complete transport network can be chosen at the right time, based on costs, travel time, or CO_2 footprint"



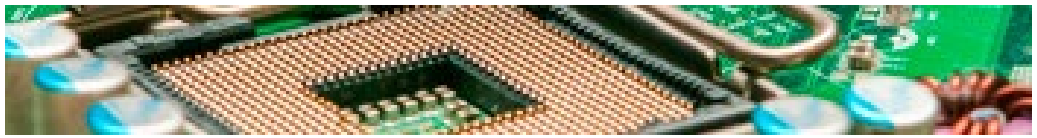
The **essential needs** are:

- Permanent knowledge on traffic information
- Availability of resources/infrastructure to facilitate fast changes between transport modes
- High communication and coordination levels among transport services of different modes
- Ability to take the decisions on the best transport mode – at any time and moment
- In **summary**, take advantage of smart IT and **optimisation** techniques to support collaborative tasks among multiple agents (i.e. shippers)



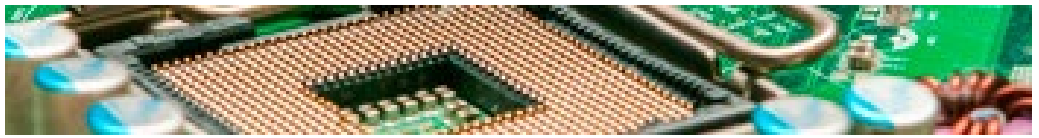
Multimodal, intermodal and synchromodal mean **only one** transport **chain** but **at least two** different transport **modes**

- it is a *hot* topic of R&D+I for green/smart cities
- a better and more efficient transport by using the most adequate modes of transport, while also reducing the CO_2 emissions
- it requires a lot of planning
- some ideas are also applicable to transport of people (**intermodal passenger transport**)



Contents Part 3

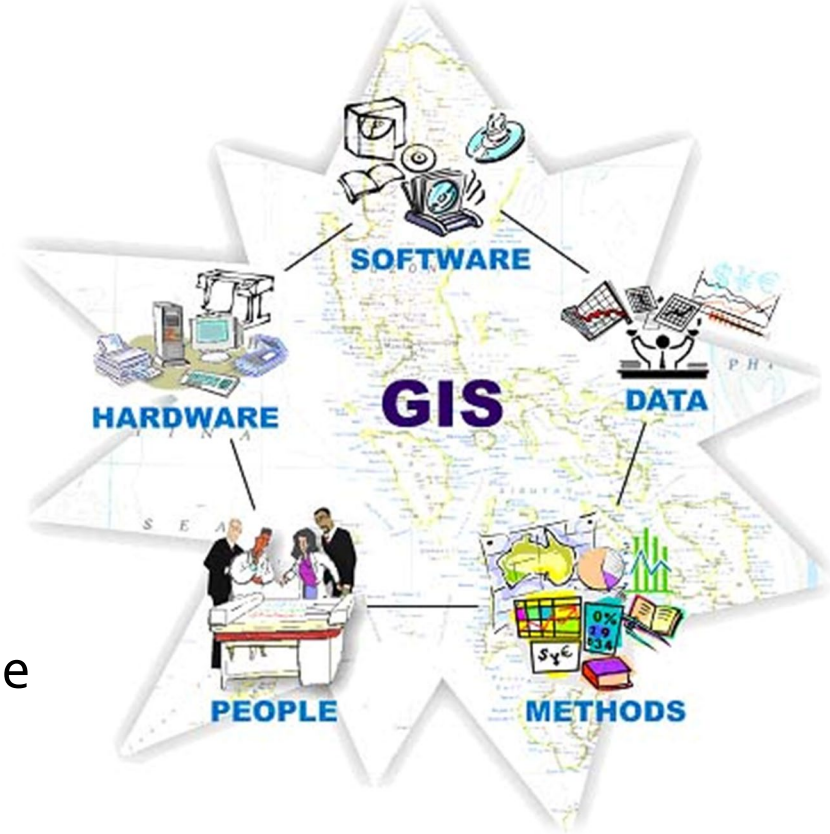
- Geographical Information Systems (GIS) for transportation (GIS-T) and logistics
- GIS for decision taking

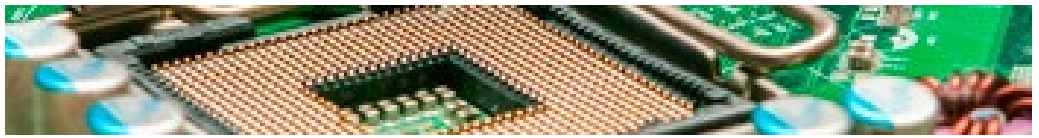


A GIS **integrates** hardware, software and data(bases) for capturing, storing, managing, analysing, and displaying **all** forms of **spatial and geographically** referenced information

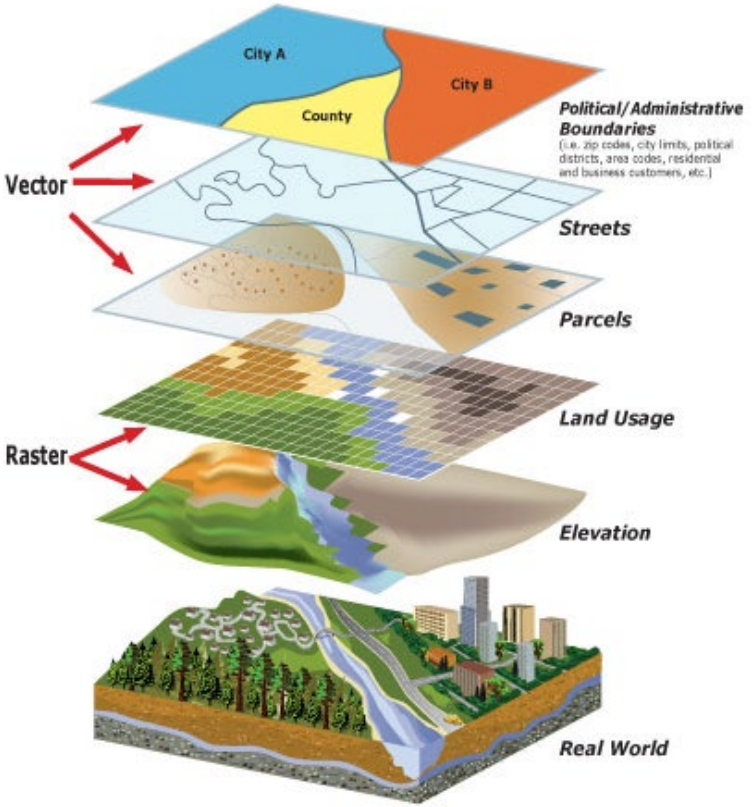
- Allows us to view, understand, question, interpret, and visualise data in many ways that reveal relationships, patterns, and trends in the form of maps, globes, reports, and charts

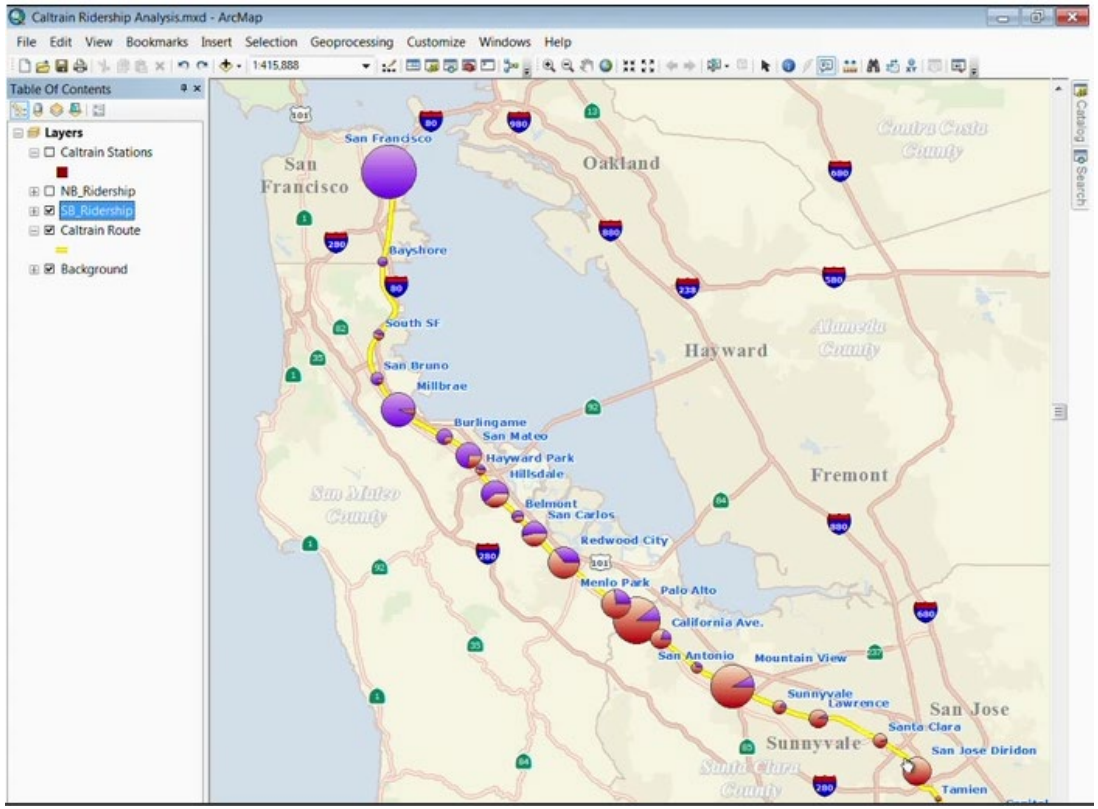
- For **transportation and logistical needs**: to get the right things to the right place (GPS) at the right time

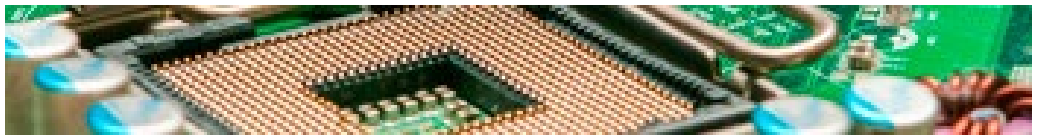




It provides **different layers** from databases that can be used for data analysis, such as potential customers, population information (age, sex, incomes, etc.), streets, geocode information, etc.

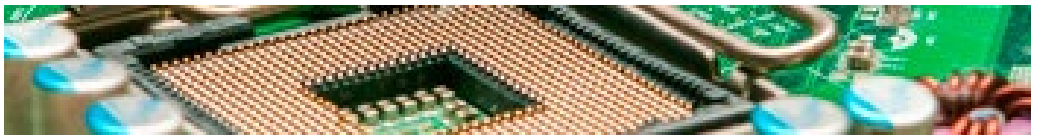






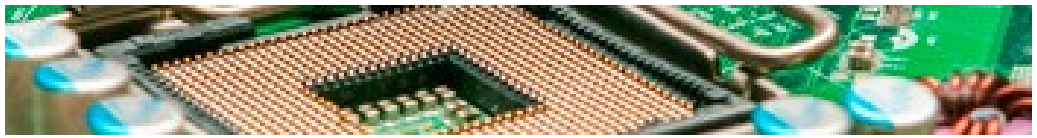
Transportation and logistics professionals all over the world have embraced **GIS technology** as a powerful tool for **managing, planning, evaluating and maintaining** their operations

- GIS tools aid in decision-making so that the business runs efficiently without compromising on quality customer service – significant cost savings
- Done by integrating data from geospatial content such as maps, images, applications and other geographic information commonly used for planning, deploying, operating and optimising transportation and logistical systems



GIS are very **useful in logistics**

- They help construct a distribution network and appropriate placement of warehouses within clusters of customers
- Ability to calculate accurate drive times – important results in business
- The cost benefit for routing and scheduling products means savings in numbers of vehicles, reduced mileage and CO_2 emissions
- They offer opportunities for dynamic re-scheduling of vehicles to take advantage of additional loading opportunities or to avoid areas of congestion
  - very **appropriate** for **synchromodality**

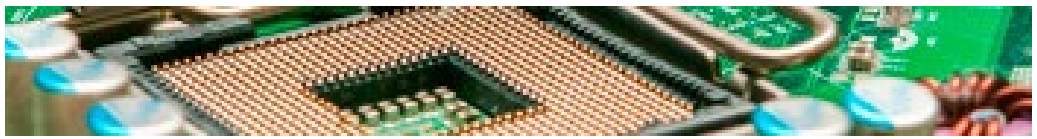


GIS for decision taking

ADMINISTRATION & INFRASTRUCTURE: GIS as a tool for strategic planning; as a spatial decision support tool for asset management HUMAN RESOURCES MANAGEMENT: Flexible workforce management based on project location PRODUCT / TECHNOLOGY DEVELOPMENT: Examination of effects of spatialization in process/product PROCUREMENT: fleet management, supply management				
INBOUND LOGISTICS: optimization of warehouse usage; logistics modelling	SALES & MARKETING: GIS as a market analysis tool; simulation of dispersion of new products; target marketing and advertising	SERVICES: route planning; dealer network maintenance; customer complaints; dispatch; maintenance forecasting	OPERATIONS: enhancing the spatial content of process or product	OUTBOUND LOGISTICS: route planning; fleet management; delivery assessment

GIS in the value chain

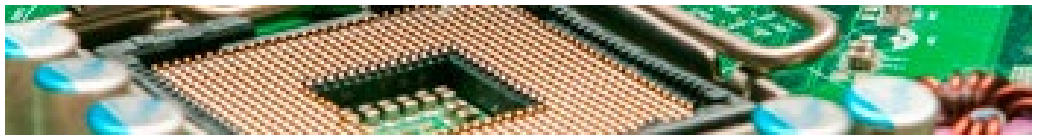
Hendriks, P.H.J. Information Strategies for Geographical Information Systems. Int. Journal of Geographical Information Science, 12(6): 621-639, 1998



Level	Description
Logistics structures	Numbers, locations and capacity of factories, warehouses and terminals
Pattern of trading links	Created by commercial decisions on sourcing, sub-contracting and distribution, and manifest as a freight network linking a company'' premises to those of its trading partners
Scheduling of product flow	The programming of production and distribution operations translate trading into discrete freight flows. Adherence to a just-in-time (JIT) regime, for example, usually requires frequent delivery of small orders
Management of transport resources	Within the framework defined by decisions at the previous three levels, transport managers still have discretion over the use of transport resources.

A taxonomy of logistics decisions

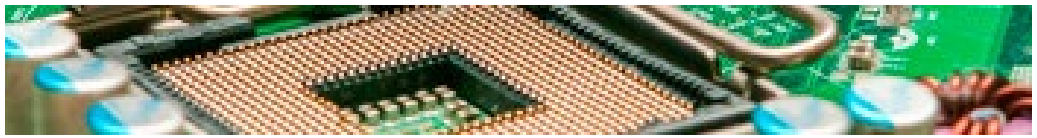
McKinnon, A.C. Logistical Restructuring, Freight Traffic Growth and the Environment. In: Transport Policy and the Environment (ed. David Banister), 1998



Level	Decision support software
Logistics structures	Strategic planning, Distribution network planning, Asset management, Performance measurement
Pattern of trading links	Supply management, Demand analysis and measurement Dealer network maintenance
Scheduling of product flow	Logistics modelling Goods receipt and despatch Dispatch Delivery assessment
Management of transport resources	Routing and scheduling Driver and vehicle performance Fleet management, Maintenance forecasting, Optimization of warehouse usage Warehouse management

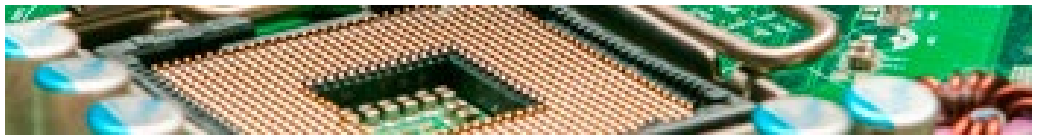
GIS opportunities to support logistics decisions

McKinnon, A.C. Logistical Restructuring, Freight Traffic Growth and the Environment, 1998



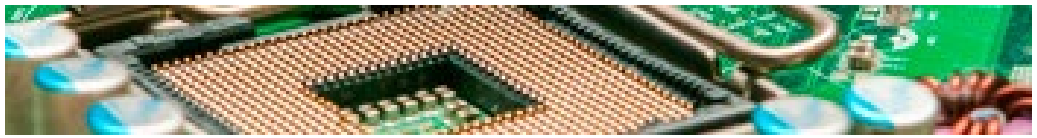
In **summary**, GIS are **useful** in the strategic, tactical and operational **decision layers**

- **Strategic**
  - plan locations for improving the existing network
  - select locations for warehouses, transfer points and hubs
- **Tactical**
  - design and evaluate routes and schedules
  - monitor and analyse traffic (e.g. congestions and accidents)
- **Operational**
  - monitor the transit vehicle to provide improved information to the user
  - route and schedule delivery on a daily basis to improve efficiency and reduce costs



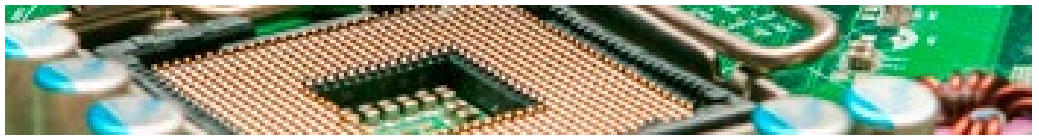
Commercial tools

- **ArcGIS**
  - http://www.arcgis.com
- **GeoMedia**
  - http://www.hexagongeospatial.com/products/gis/geomedia
- **MapInfo**
  - http://www.mapinfo.com
- **GeoConcept**
  - http://es.geoconcept.com



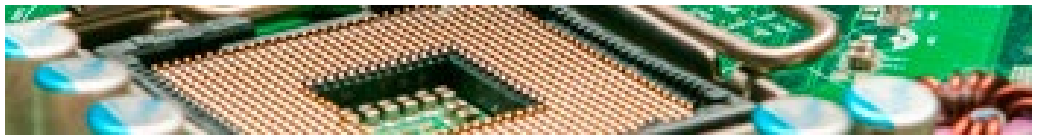
Non-commercial tools

- **gvSIG Desktop**
  - http://www.gvsig.com
  - https://www.youtube.com/watch?v=oyAcgY7KJiw
- **QGIS**
  - http://www.qgis.org/es/site
- **GeoServer**
  - http://geoserver.org
- **MapServer**
  - http://www.mapserver.org
- **Software** based on:
  - **Microsoft Bing Maps**, **Google Earth** and **OpenStreetMaps**



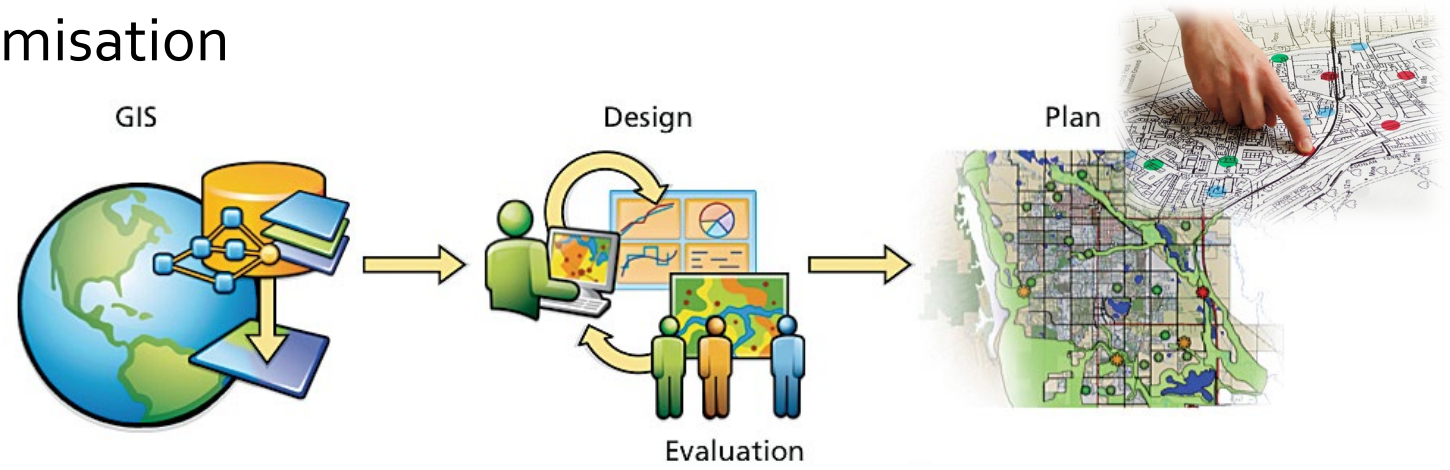
Spatial and geographic databases

- **PostGIS**
  - http://postgis.net
- **Oracle Spatial and Graph**
  - http://www.oracle.com/technetwork/database-options/spatialandgraph/overview/spatialandgraph-1707409.html
- **MySQL and spatial extensions**
  - https://dev.mysql.com/doc/refman/8.0/en/spatial-types.html
- **SQL Server and spatial data**
  - https://msdn.microsoft.com/en-us/library/bb933790.aspx
- **DB2 with spatial extensions**
  - https://www.ibm.com/developerworks/ssa/data/tutorials/dm-1202db2spatialdata1/index.html



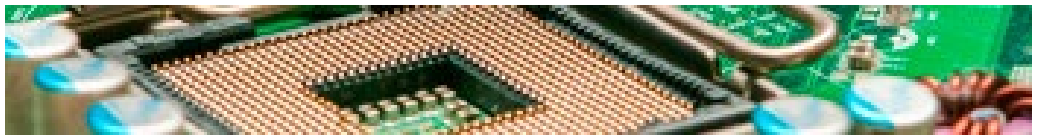
GIS are very **powerful tools** for decision taking

- use of spatial and geographic databases with different layers and levels of data
- used for analysis, evaluation and to support decisions (e.g. select potential areas for expansion)
- also provide options for solving path problems and route optimisation

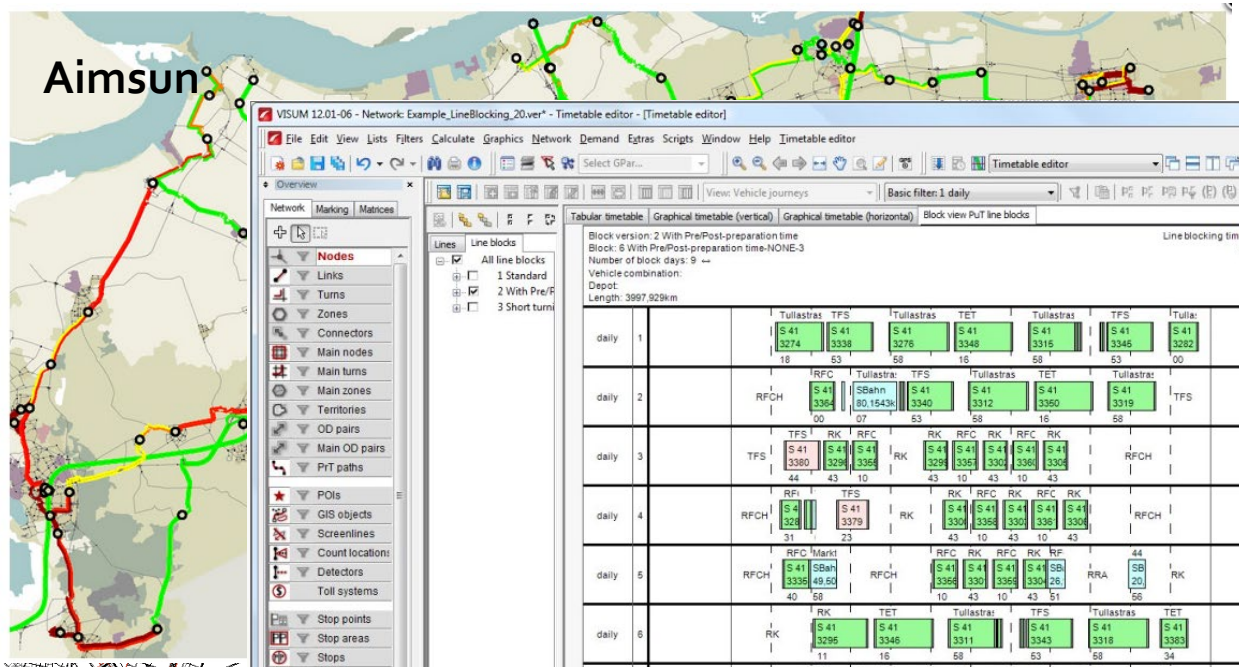


Although **they are not** exactly **GIS**, there are other **related tools**

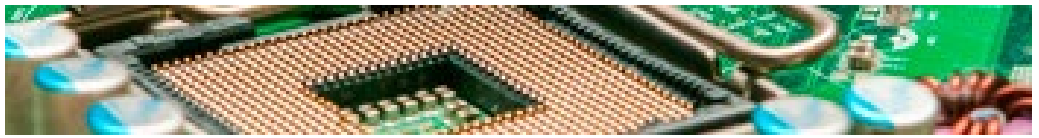
- used for modelling, simulation and experimentation of urban mobility and traffic, facilitating the evaluation of infrastructure changes as well as policy changes before implementing them on the road
- **non-commercial**:
  - **Matsim**, http://www.matsim.org
  - **Sumo**, http://www.dlr.de/ts/en
  - **Sesam**, http://130.243.124.21/sesam, https://www.eclipse.org/sumo/
  - **Transims**, https://code.google.com/p/transims
- **commercial**:
  - **PTV Visum**, http://vision-traffic.ptvgroup.com
  - **Aimsun**, http://www.aimsun.com



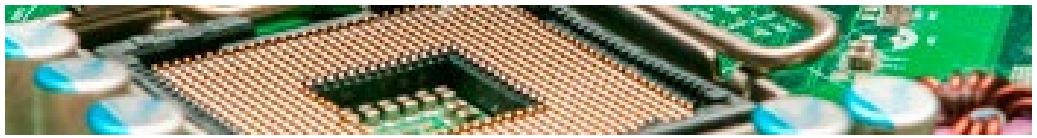
Examples of traffic simulation tools



PTV Visum



As a **summary**, in **a logistics setting** we need **integrated tools** like these



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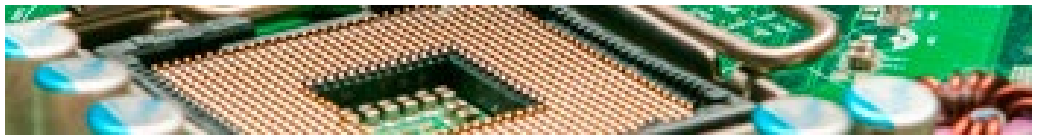

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