Net-WMS

SPECIFIC TARGETED RESEARCH OR INNOVATION PROJECT

Networked Businesses

D.2.1 –Net-WMS vision of future packing chain in modern WMS (Version 1)

Due date of deliverable: 31 August 2007

Actual submission date: 17 October 2007

Start date of project: 1 September 2006 Duration: 36 months

Organisation name of lead contractor for this deliverable: KLS OPTIM

Project co-funded by the European Commission within the Sixth Framework Programme (2002-2006)

COVER AND CONTROL PAGE OF DOCUMENT	
Project Acronym:	**Net-WMS**
Project Full Name:	Towards integrating Virtual Reality and optimisation techniques in a new generation of **Net**worked businesses in **W**arehouse **M**anagement **S**ystems under constraints
Document id:	Net-WMS D2.1 deliverable report
Document name:	D2.1 - Net-WMS vision of future packing chain in modern WMS
Document type (PU, INT, RE, CO)	PU
Version:	1
Submission date:	October 17th, 2007
Authors: **Organisation:** **Email:** **Authors:** **Organisation:** **Email:** **Authors:** **Organisation:** **Email:**	Abder AGGOUN KLS abder.aggoun@klsoptim.com Adrien Lauer PSA adrien.lauer@mpsa.com . Olivier GUASH PSA olivier.guash@mpsa.com

Document type PU = public, INT = internal, RE = restricted, CO = confidential

ABSTRACT:

This deliverable details the complete process of preparation of an expedition using novel technologies. The document highlights the impact of the new tools on the complete chain in modern warehouses.

KEYWORD LIST:
Network of Warehouses, Packing, Scheduling, Dispatching, Palletisation, Border of the line, Service Oriented Architecture, Java 2 Enterprise Edition, Optimisation, Virtual Reality, Interactivity.

MODIFICATION CONTROL			
Version	Date	Status	Author
1	15-10-2007	V1	Abder Aggoun

Deliverable manager

- Abder, Aggoun, KLS

List of Contributors

- Abder Aggoun, KLS OPTIM
- Olivier.Gourguechon, PSA
- Alessandro Leverano, CRF
- Camille Chigot, CEA
- Filipe Carvalho, WID

List of Evaluators

- Philippe GRAVEZ, CEA
- Philippe Rohou, ERCIM

TABLE of CONTENTS

1 – Introduction

The first objective of this report is the identification of general characteristics of a complete chain of expedition in terms of knowledge representation, sharing knowledge, connectivity, mobility, browser-based environments, designing packing models, computing the number of models to pack all items of an expedition, placement in the preparation zones, placement of packed items in vehicle according to the order of the visited customers, and planning and scheduling the packing activities in a WMS.

Based on requirements gathered in the Net-WMS project, the second objective is to give a vision of future packing chain in modern WMS. The aim of this objective is to focus on advanced tools and their contribution to modern WMSes in term of reactivity, flexibility, robustness and cost efficiency.

2 – Supply Chain Organisation

The term supply chain management was coined by consultant Keith Oliver, of strategy consulting firm Booz Allen Hamilton in 1982. Supply chain management (SCM) is structured into complementary processes of planning, implementing, and controlling the operations of the supply chain with the purpose of satisfying customer requirements as efficiently as possible. The supply chain of a manufacturing enterprise is a world-wide network of suppliers, factories, warehouses, distribution centres and retailers through which raw materials are acquired, transformed and delivered to customers. The organization is so complex that the complete process is structured into a chain of interconnected modules (see the figure below). Each module can be associated to a business sector. In order to optimize performance of the complete process, supply chain functions must operate in a coordinated manner.
The component concerned in this presentation is the WMS component running a warehouse, an entity that stores products and maintains an inventory level for each stocked product.

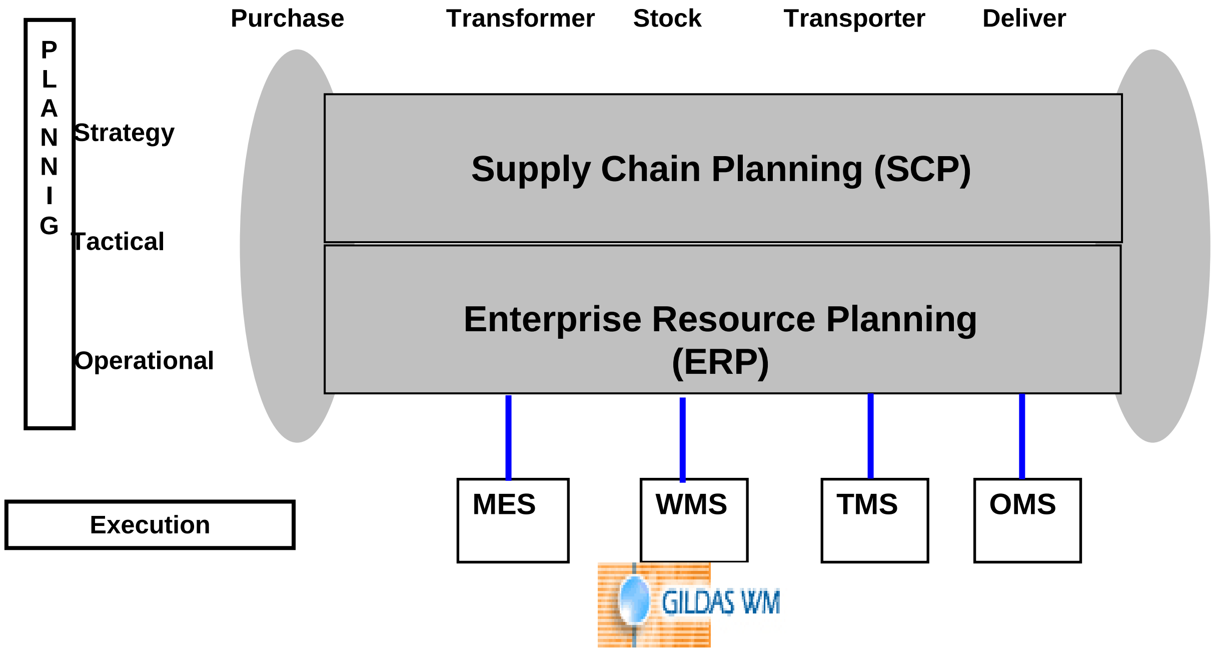

Figure 1: Supply Chain Management Organisation
(for acronyms, see the glossary at the end of this document)

3 Contribution of advanced tools to modern Warehouse Management Systems

3.1 Glance on new logistics

The architecture of the Supply Chain Execution is evolving, as shown in figure 2. An intermediate level N2O between N1 and N2 is getting more and more interests. A warehouse management system (WMS) is initially a system to control movement and storage of materials within a warehouse. Its role is expanding to include light manufacturing, transportation management, order management, and complete accounting systems.

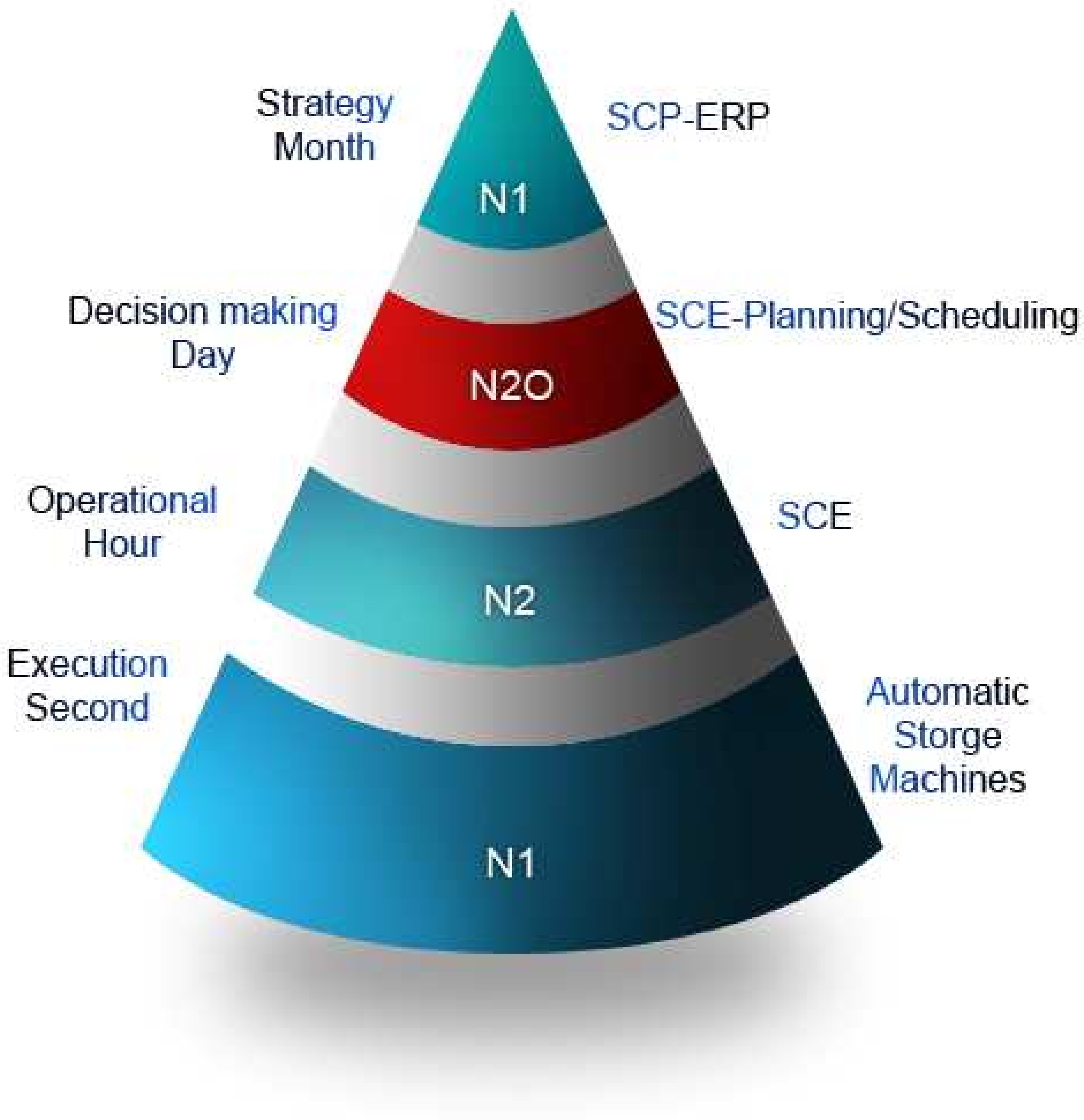

Figure 2: Architecture of SCM

As highlighted in the Net-WMS project, existing WMS provide advanced features to manage the movement of items within the warehouse, but fail to comply with the increasing demand on more numerical handling (availability of digital information), such as: how to pack items in a container, how many cartons needed to pack customer items, how to schedule activities of warehouse taking into account in-house constraints (manpower capacity) and suppliers/customers constraints to finish the preparation in time, in which order to pack items in a pallet, and the position of pallets in a truck according to the customers to visit. Thus, services like scheduling, advanced packing tools, optimal filling of containers and trucks subject to delivery constraints are lacking. These services are grouped in the N2O level (O as in Optimisation). One can see that all these new services are required for daily operational management.

Modern WMSes will comply with the new architecture of a SCM.

3.2 Warehouse management system

In order to adequately run a warehouse, there is need for a warehouse management system (WMS) as well as other software components, so as to provide the end-users with an efficient operational system. In most cases, a WMS is connected to a host system (ERP, Accounting systems,...). Today, the demand is to share a set of limited information with third parties and especially transport companies.

A WMS is used to control and monitor the main operations of the warehouse like handling reception, processing orders, order picking, order shipping and inventory management. Indeed, the basic logic in handling a warehouse is the capability to exploit a combination of item, location, quantity, inventory, unit of measure, resource, order information and activity to determine where to pick, how to pick and in what sequence to perform these operations. The main functionalities provided in a WMS make possible the automation of the flow of information and the coordination of key activities in a warehouse or in a distribution centre, in order to maximize efficiency and increase customer satisfaction.

The aim of this section is not to describe the complete WMS. The focus is placed on operations where decision making tools can bring potential added values.

A WMS is designed around the following basic functionalities:

- Inventory
- Control Storage Location Management
- Quality Control Interfacing
- Order Selection
- Automated Inventory Replenishment
- Receiving
- Shipping
- Operator Productivity
- Report Generation
- Preparing activities of orders
- Manual scheduling of activities

3.3 Concepts

Many WMS editors are specialised in different sectors. For example, one can find specialised solutions in agro food, manufacturing or pharmacies. Parameterisations of dedicated solutions for new domains require heavy development.

The trend is to work with concepts. KLS has developed a new methodology of modelling processes by using concepts:

- Zone
- Event
- Flow

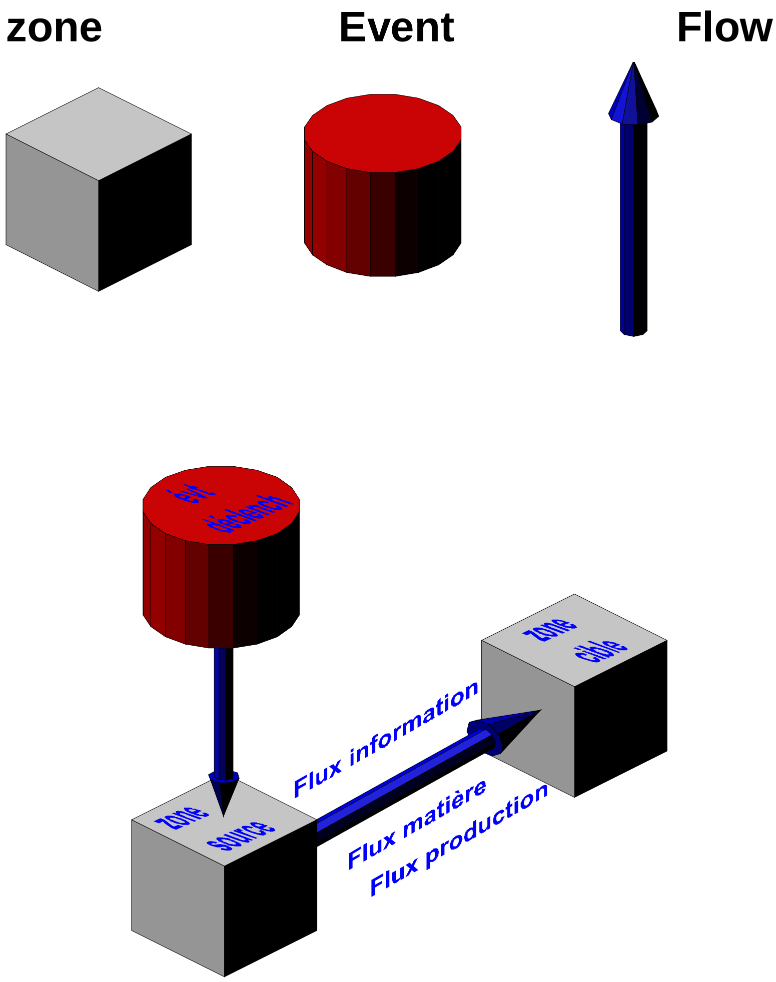

Figure 3: Concepts: three elementary objects, a multitude of combinations

The warehouse management system can be seen as a tool for modelling the flow of goods, stored in **zones** within the warehouse. These **flows** are then associated with products and implemented through orders, procurement and delivery processes which are controlled by management functions. All operations like command preparation, replenishment and reception are actions which are triggered by a sophisticated **event** management module.

3.4 Process of modelling

Modelling a new process can be done in three steps:

- Cartography cutting / structuring
- Qualification of zones

- Dynamics of the flows of the goods.

Step 1: Cartography cutting / structuring

The first step is naturally to describe the physical warehouse and in particular areas, process of identification of each zone (logical and / or physical).

Figure 4: Cartography

Step 2: Qualification of zones

Each of the zones will receive appropriate management models. One can find three types of zones:

- Areas which content is not managed per se (e.g. suppliers and customers zones). Those areas will be sources or targets of incoming and outgoing flows.
- Transit zones which may be decomposed into sub-zones (e.g. docks, shuttle inter-sites)
- Storage areas whose locations can be determined from information: Site-zone-zone-column-level position-depth.

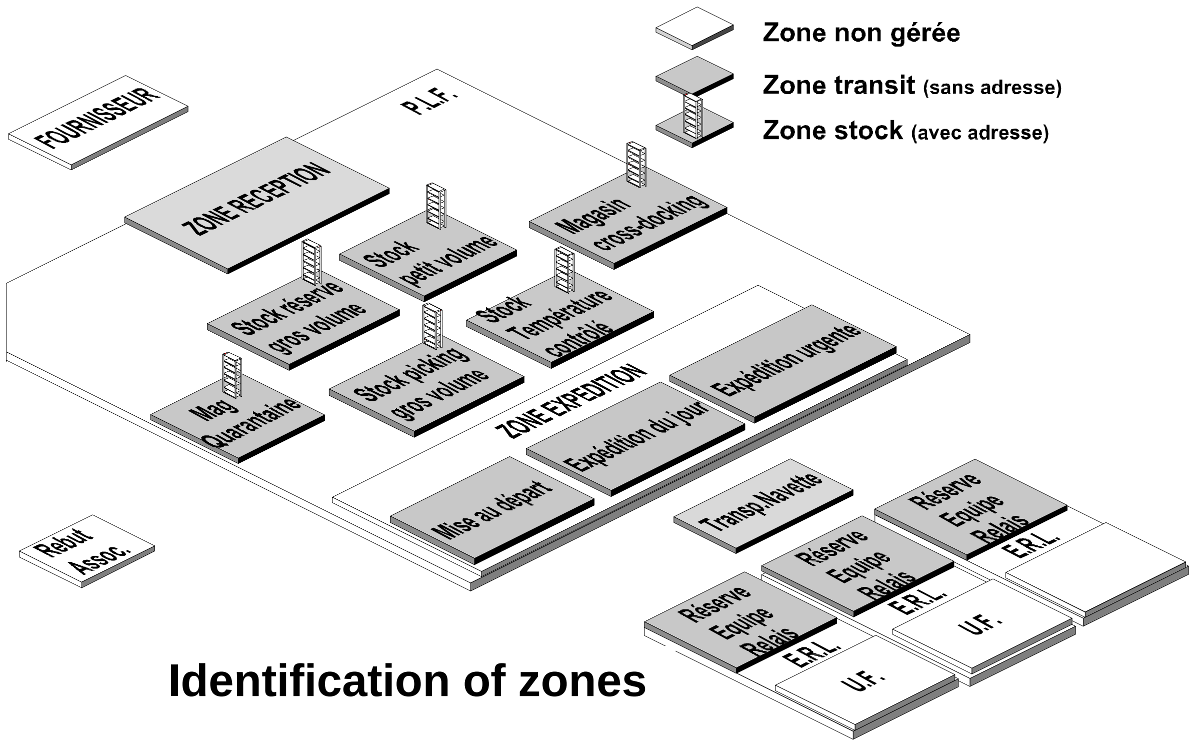

Figure 5: qualification of zones

Step 3: Dynamics of the flows of goods

Flows can be described, according to four types, identifying the source area, the target area as well as all the parameters that characterize the flow depending on its type: Rule debit product (FIFO), rules for monitoring lot:

- Flow of supply which are input streams;
- Transfer flows between two storage areas;
- Consumption Flow which are outgoing streams;
- Information flows which transform the characteristics of an object stored without any movement (e.g. changes of good status).

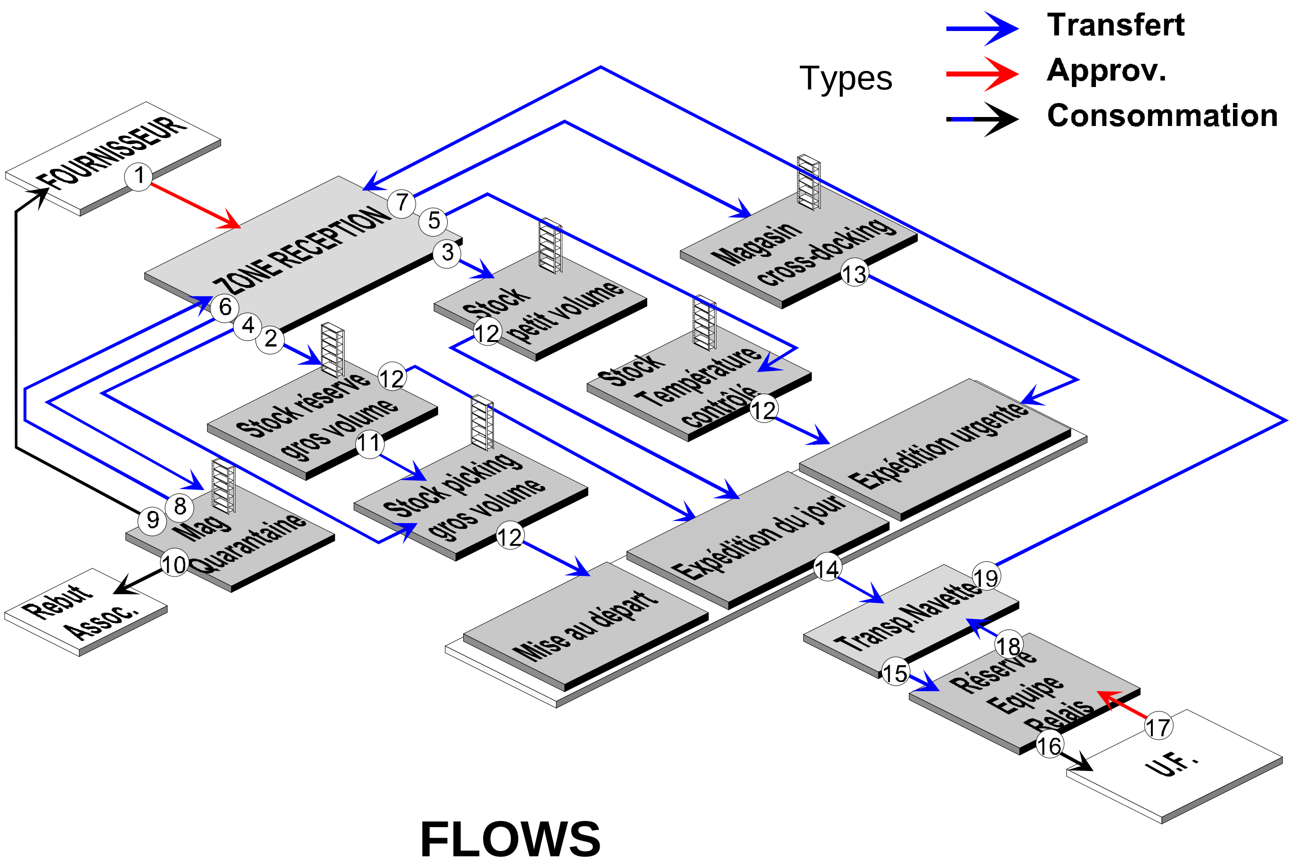

Figure 6: Dynamic of flows

The event management is a key point for the automation of the process: creation / modification / deletion of data, or launching a function according to some parameters. The handling can be triggered to perform a function of the software, write to the database or to notify an alert via email or printing.

There are many advantages of these concepts, among them one can mention:

- Users can master the tool and can achieve by themselves subsequent deployments. The advantage is that users are not just simple users for the exploitation, they are actors. Dedicated training is required to improve their qualifications.
- Traceability is a key point in the deployment of a warehouse management systems. These concepts enable the automation of the traceability with less effort.
- Capabilities of the tool to model complex processes.
- Modelling and deployment of evolving solutions.
- Capabilities of the tools to be used in many domains.

3.5 New requirements

The role of a WMS application is evolving due to the market demand. There is a demand to include extra functionalities which are not originally in the scope of a standard WMS. Such functionalities are formally parts of TMS (Transport Management System) like advanced packing functionalities that are lacking in most existing WMS of the market and optimization of vehicle loading. While experts try to separate the different businesses (MES, WMS, and TMS), the business in the WMS is basically evolving to satisfy the customer demand.

3.6 Networked J2EE architecture

Networked architectures play an important role in current technology information systems, and constitute a crucial feature of supply chain management. The industry requirements include highly available, secure, portable, reliable and scalable services that integrate distinct enterprise information systems and provide several front-ends for users across a network. The integration of such services, data and business logic is usually provided by middleware components, which - putting it simply - are server-side software solutions that connect and integrate those systems and resources potentially spread across a network.

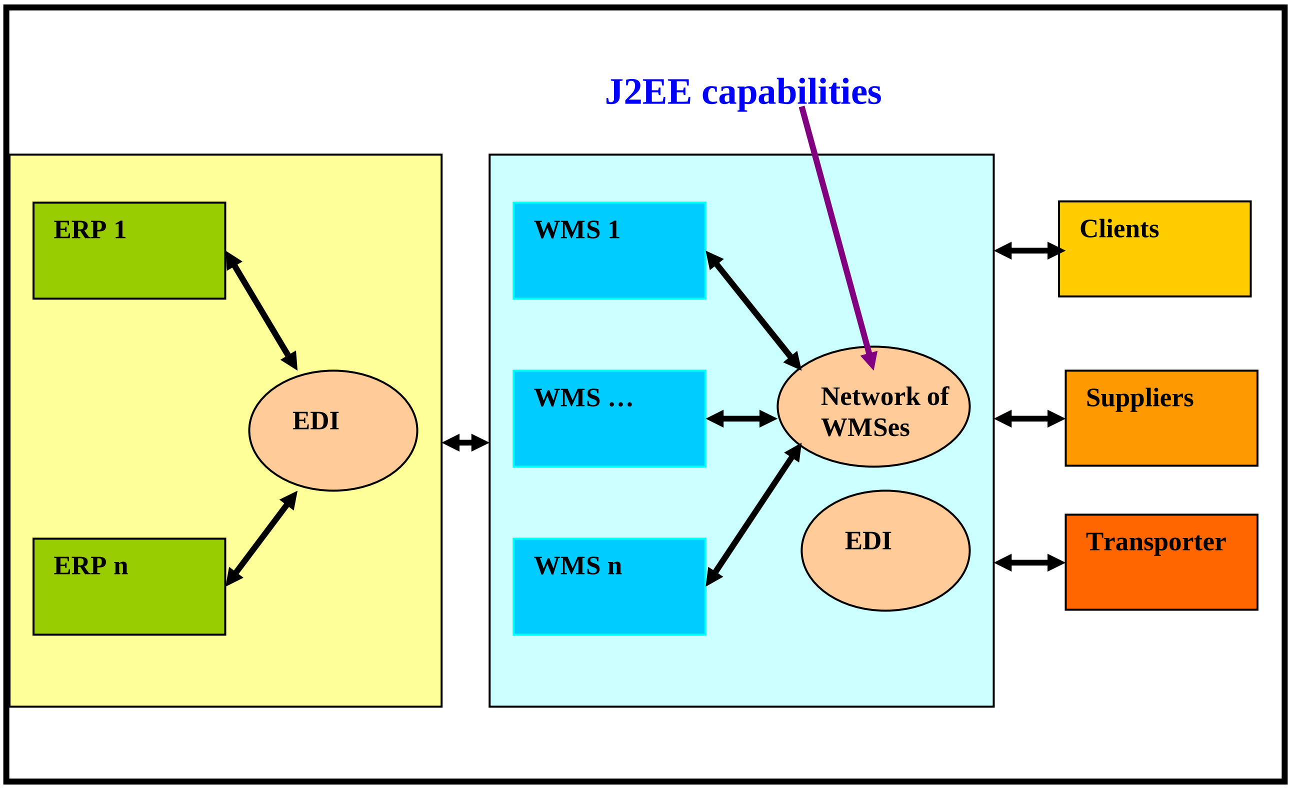

Figure 7: Network of warehouse management systems

SOA (Service Oriented Architecture)

The Net-WMS platform suggests a highly dynamic Service Oriented Architecture (SOA) where contents are supplied as services in order to be displayed in several systems and graphical dispositions.

The requirements also suggest that reusability, flexibility, usability and scalability are important considerations. The driver behind SOA is precisely the idea that technology should quickly adapt to rapid changes in the business landscape. In some respect, the “service oriented” aspect of SOA implies that technology is designed to serve end-users and business priorities.

Many organisations are looking to SOA solutions to increase their standard IT infrastructure, to provide an environment for re-usability, and ultimately to increase business agility.

In “Management Update: A Portal May Be Your First Step to Leverage SOA” [G. Phifer, October 12, 2005, Gartner inc.] Gartner predicts that SOA will be the basis of 80 percent of all IT development projects by 2008.

SOA is made possible by key technologies such as SOAP / Web Services, XML, EJB, and the Struts Application Framework, which in their respective ways allow loosely coupled business logic or services to be exposed to various consumers, which can be applications or end users.
When an effective SOA is in place, an organization can quickly create “Composite Applications” which are collections of business services exposed through standard interfaces in a suitable framework for presentation to business actors.

In “Portals Provide a Fast Track to SOA” [G. Phifer, July 15, 2005, Gartner inc.] Gartner recognizes the portal as the first logical step in leveraging SOA and one of the most natural frameworks for such interaction between services and users.

The portal is the context in which composite applications enabled by SOA are presented to the end user. When business processes are presented abstracted from the complex technologies behind them, users will adapt quickly to those processes without distraction. The reusability of services to assemble different composite applications is a further benefit of an SOA, reducing IT expenditures for development and maintenance, and aligning an organization technologies with the business processes that drive them.

J2EE Java 2 Enterprise Edition

Before the advent of J2EE, middleware solutions were highly proprietary and restrictive to specific vendors and products, even with limited features and compatibility, and no interoperability or portability across different solutions was provided. Industry standards and common practices were rare and many features were either proprietary or left to the choice of vendors. J2EE is middleware architecture for developing and deploying multi-tier, distributed, enterprise scale business applications. Applications that follow the J2EE standards inherently benefit from features such as scalability, portability, reusability, security, and load-balancing.

J2EE represents the maturity and seasoning that middleware technology has undergone over the years by learning from the mistakes of the past and addressing all the essential requirements of the industry. It also provides enough room for future developments. While developing this standard, Sun Microsystems collaborated with other major vendors of middleware, operating systems, and database management systems-including IBM and Oracle.

At its core, J2EE is a set of standards and guidelines that defines how distributed n-tier applications can be built using the Java language. Developers build their applications on the top of these standards while middleware infrastructure vendors ensure compatibility to these guidelines set forth by J2EE. Thus, J2EE applications can be ported and deployed across several application servers, with minimal or no code-level changes.

A J2EE enterprise-level networked architecture addresses several requirements, such as:
Net-WMS D3.1 page 11 of 52 Net-WMS FP6-034691:

- Remote method invocations: logic that connects a client and server via a network connection. This includes dispatching method requests, brokering of parameters, and more.
- Load balancing: clients must be directed to the server with the lightest load. If a server is overloaded, a different server should be chosen.

- Transparent fail-over: if a server crashes, or if the network crashes, clients must be rerouted to other servers without interruption of service. This shall happen fast enough according to the business criticality.
- Back-end integration: code needs to be written to persist business data into a database as well as integrate with legacy systems that already exist.
- Transactions: transactions are required to protect data integrity and consistency namely when two clients access the same row of the database.
- Clustering: if the server that contains state crashes, clustering enables such state replication across all servers so that clients can use a different server.
- Dynamic redeployment: software upgrades can be allowed while the system is running. However, this feature may be disabled for performance reasons.
- Clean shutdown: if a server is required to be shut down it must happen smoothly such that clients already posting requests to the server are not abruptly interrupted.
- Logging and auditing: if something goes wrong a log is available for consultation in order to determine the cause of the problem, and help in its debug.
- Threading: having many clients connecting to a server requires the capability of processing multiple requests simultaneously. This means that the server application must be coded to be multi-threaded.
- Object life cycle: the objects that live within the server need to be created or destroyed when client traffic increases or decreases, respectively.
- Resource pooling: if a client is not currently using a server, that server's precious resources can be returned to a pool to be reused when other clients connect. This includes sockets (such as database connections) as well as objects that live within the server.
- Security: the servers and databases need to be shielded from saboteurs. Known users must be allowed to perform only operations that they have rights to perform.
- Caching: many objects are used by the same clients over and over again. There is no reason why they should be instantiated and destroyed on every client request. There are performance increases when such objects are cached and reused in the same context.

Modern warehouse management systems have to be compliant with J2EE technology for interoperability requirements and to take advantages of capabilities offered by networked warehouses. Such demands are coming from users, suppliers and customers.

3.7 Decision making modules

Each warehouse has its own working rules and processes. The general process follows the important operations:

- **How**
    - Process definition of products.

- **What**
    - Definition of resources (persons and equipments)
    - Estimation of the capabilities of the warehouse

- **When**
    - Short term scheduling of family of activities (reception, replenishment, packing, loading, …). Some of the activities may share pools of resources.
    - Dispatching activities

- **Metrics**
    - Tracking, analysis and data collection per family of activities.

In addition to those operations, one can add the environment context:

- **Internet**
  - Network of warehouses: collaborative work of warehouses of the same organisation, collaborative work of grouped warehouses (alliances).
  - Network organisation: transporters, clients and suppliers are connected (linked), logistics information is available in real time.

- **Expertise**
  - Knowledge-based packing expertise: the expertise is structured and enriched over time. This expertise is exploited through collaborative architectures.

- **Advanced visualisation tools**
  - **CAD tools**: new generation of software tools (with a reasonable price) for improving the process of definition of new products.
  - **Virtual Reality**: new capabilities of advanced tools to navigate through the warehouse.
  - **Rich client:** capabilities of rich clients to access information in a network of warehouses or platforms.

In many warehouses, the “**What**” and the “**When**” operations are implemented by using in-house expertise. In future and modern WMS, decisions will be based on the exploitation of the results of the “**Metrics**” operations. In manufacturing and warehouses, “**Metrics**” operation requires taking into account the new context (Internet, knowledge-rules systems, advanced visualisation, quality of available open-source software). Therefore decision making tools (scheduler, packing and dispatching) will be used in various contexts:

- **Building a new warehouse**: estimation of the resources, definition of scheduling scenarios, definition of models of packing, definition of scenarios of dispatching the loads over vehicles. In this context, decision tools are part of modern warehouse management systems.

- **Working warehouses**: the exploitation of the “**Metrics**” result will show the bottlenecks (bad scheduling activities, bad initialisation of the resources), wasted materials (more cartons, pallets are not correctly optimised; quality is not satisfactory). In this context, decision tools are new modules and require an efficient integration to the existing warehouse management platform. The SOA technology is a cheaper and efficient solution for existing solutions.

- **Environment**: decision making tools will contribute to reducing the number of cartons, pallets and used vehicles.

- **Training:** Modern tools will ease access to the information and especially to the expertise.

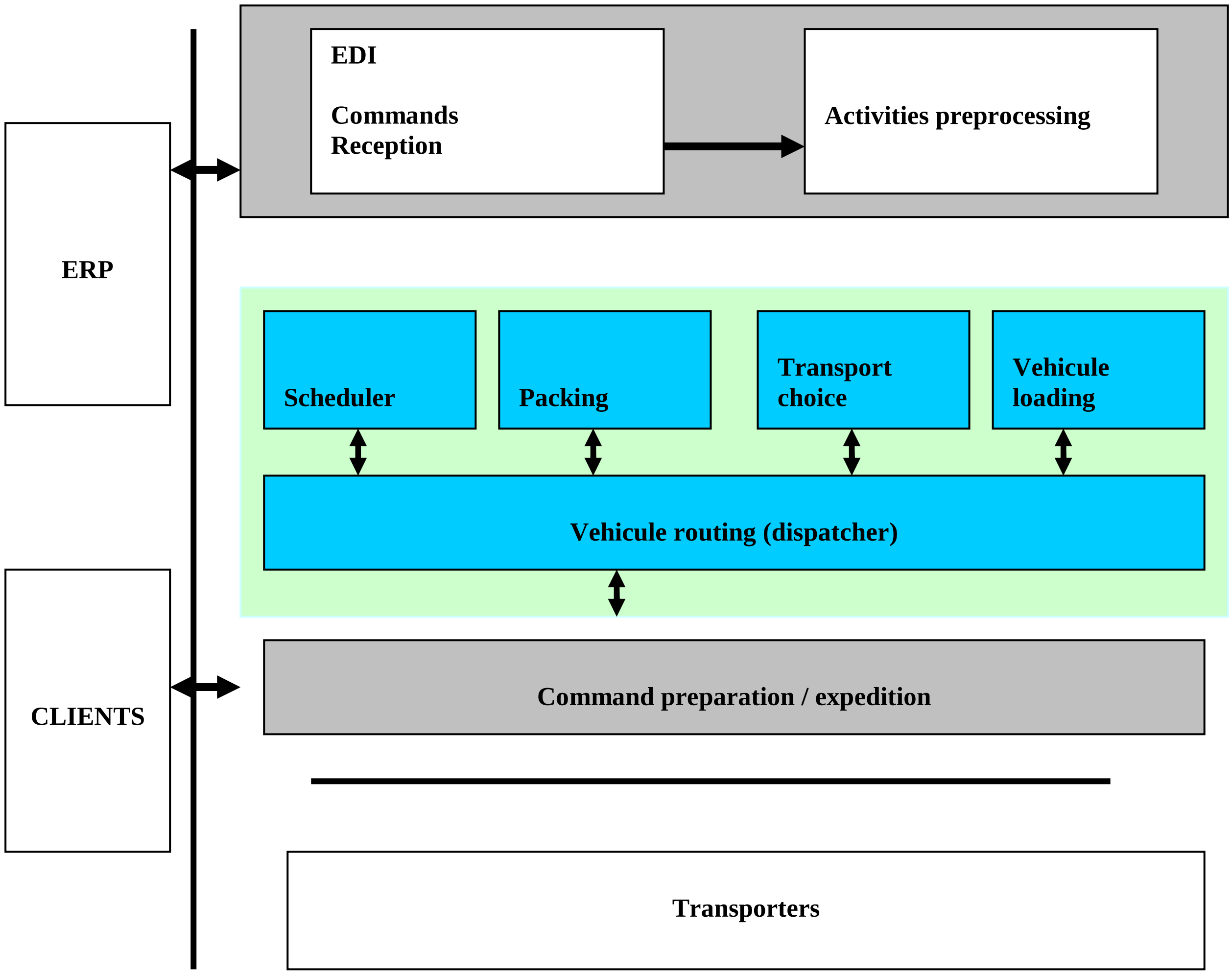

Figure 8: Architecture of advanced WMS

The figure "Architecture of advanced WMS" highlights the main components of a warehouse node in a network of warehouses, a standard and a modern warehouse in a near future.

This paragraph describes inputs of the scheduler module.

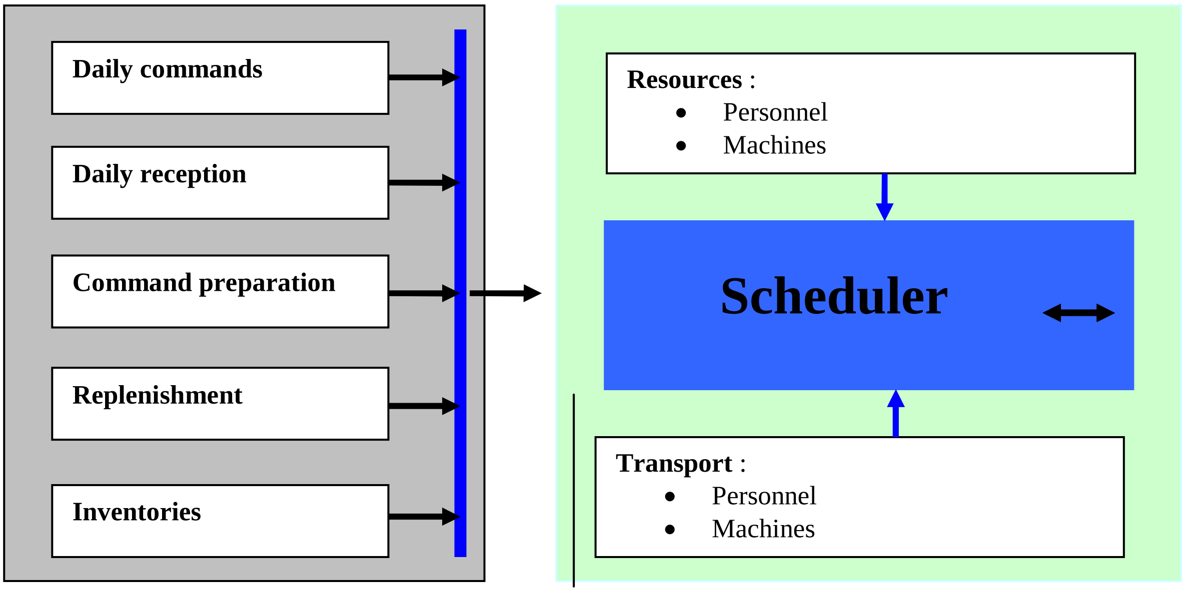

Figure 9: Scheduler component

In modern warehouse, scheduling activities play an important role. It is important to state that the objective is not to minimise the number of resources, but to improve the quality and to fulfil the new environment constraints of collaborative platforms.

3.8 Conditioning, packing and palletisation

Nowadays, warehouses mainly focus on palletisation. Future packing systems require generic packing tools with capabilities to pack nested items. A typical example in a car manufacturer warehouse where batch packing is structured into three steps:

- **Level 1**, which corresponds to the conditioning of the parts (see the figure below).
- **Level 2,** which corresponds to the packing of the parts or their associated N1 conditioning**.**
- **Level 3,** which corresponds to the packing of N2 packing of the complete batch in a final loading plan. The application will have to make it possible to work on these 3 levels separately and in a specific way (N1 or N2 or N3), or on several levels simultaneously (N2+N3 or N1+N2+N3).

Advanced packing tools are generic with the following capabilities:

- Palletisation of mono-reference orders;
- Palletisation of multiple reference orders;
- Optimisation of loading plans for heterogeneous and non-stackable pallets;
- Minimisation of the total length of virtual loads.

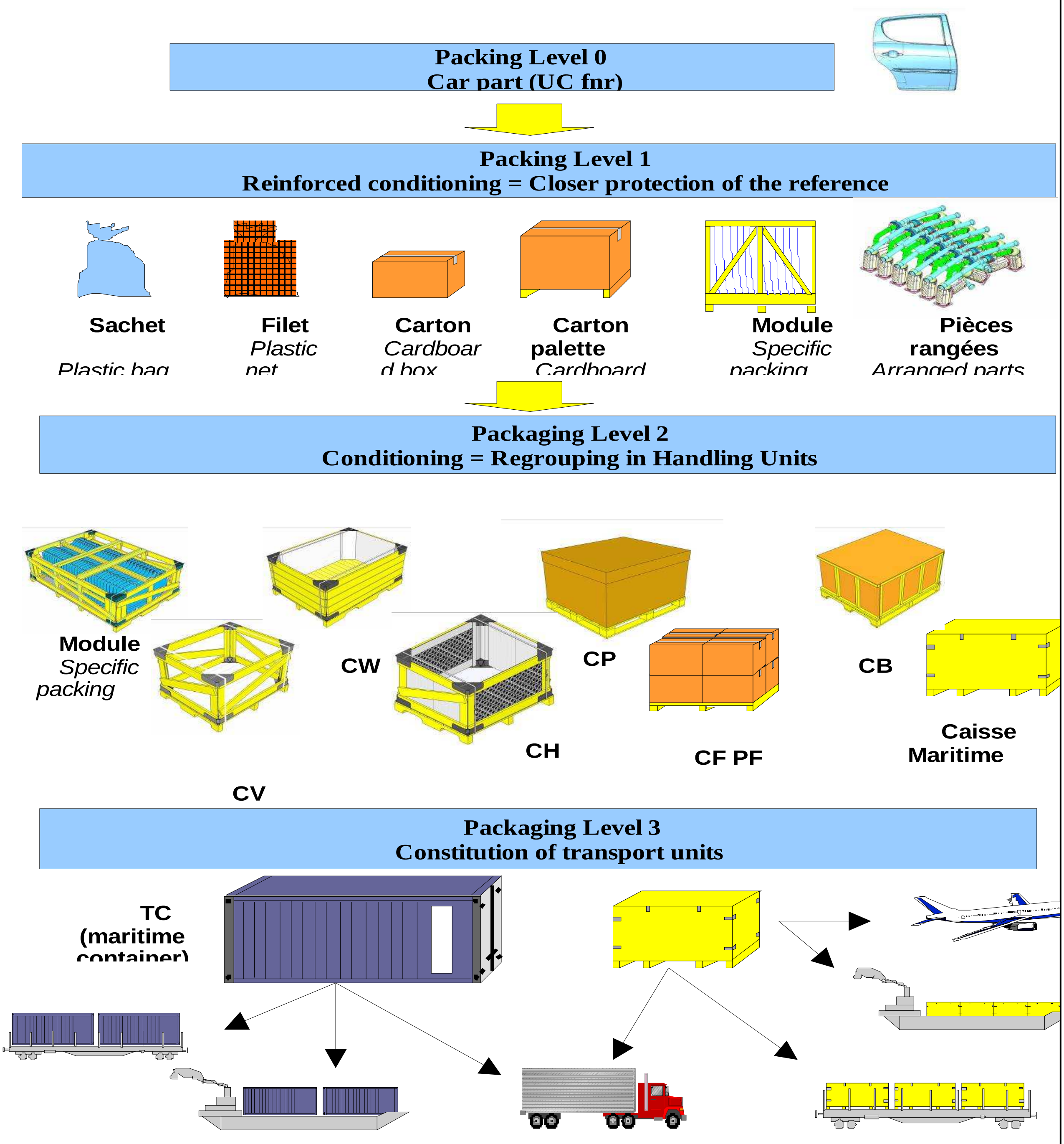

Figure 10 : Conditioning parts at PSA

The objective is to allow networked subsidiaries of a company in charge of the CKD (PSA terminology) shipping to design and optimise the conditioning and the packing. The resulting containers are then delivered by sea, ground or air transport towards the assembly factories, which have the responsibility for assembling or manufacturing the vehicles.
The packing tool will allow the end-users:

- To work in simulation mode when the physical parts are not available.
- To optimise the volumes sent to the assemblers. The reduction of the packing material and the number of containers necessary for the routing is an important factor of profit.
- To be much more reactive in taking into account the vehicles evolution (changes of parts, change of the rate of local integration).
- To re-use existing solutions. This will generate profits and avoid questioning currently used optimised processes or industrial devices in place.

Palletisation

Warehouses use various types of pallets ranging from **wooden boxes, pallets, boxes, crates, drums to wooden palletisation for export packing.** They are involved in manufacturing; various types of packaging are used for household, industrial, machinery, heavy type of packing and export quality packing.

The process of palletisation falls under a set of steps:

- identification and selection of the type of pallet,
- placement of the pallet on the floor,
- arrangement of conditionings (cartons, boxes, material, …),
- wrapping with films,
- assembling top with side plants,
- strapping with iron or plastic,
- stuffing,
- and then finally latching.

<u>Example of constraints:</u>

The purpose of the packing optimisation tools is to provide capabilities to model packing and to take various constraints into account:

- pallets have different dimensions (length, width, height),
- maximum height (this depends on the stacking parameter),
- maximum weight,
- maximum volume,
- stability,
- Structuring the pallet in layers,
- Stackability of items on the pallet,
- Visibility of bar codes on sides
- …

Indeed, when packing bags onto larger trays (pallets) so that they are packed as efficiently and neatly as possible, standard constraints must be taken into account by standard packing systems, such as bag dimensions and weight, details of how bags are arranged on the pallets …

Pallets are stacked safely, take up less space and give the customer a feeling of quality. The system can choose the best palletisation pattern for particular pack sizes, pack weights and pallet sizes. Cases and pallets can be uniquely identified with automated labels, detailing product and bar code information, which enables traceability by text or codes.

Example of knowledge rule:

The boxes must be placed so as to cover as much as possible the width of the EU (Expedition Unit) in priority, except when the volume of the EU can be fully used (see example below).

Top view:

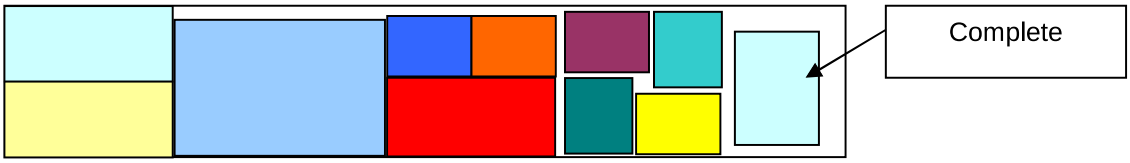

Figure 11: Example of knowledge rule

Remark: the last EU of a loading plan cannot always be optimised at 100%. One will thus spread out the boxes in the length and the width of the EU rather than in height

3.9 Border line configuration

All the parts that are assembled to the car body on the main assembly line are kept in the so-called line-side storage prior to assembling them into the car. The exceptions are the engine and the driving system that are assembled in advance, and the seats and wheels that arrive just-in-time. The line-side storage area is clearly partitioned into sections belonging to specific workstations. In each such section, the parts assembled at the corresponding workstations are stored. The number of parts belonging to a workstation is between 5 and 30.

Since storage space is very scarce, only one MOP (Means of Packing) of each part is kept there. The parts in their corresponding MOPs are arranged in one line on either side of the assembly line. The typical storage means are as follows:

- The metallic cases used to pack large and heavy parts are kept directly on the floor;
- Cardboard boxes and odettes are stored on different shelves. The most often used shelf structure is a gravity shelf that exists in only one, uniform size, but can be mounted with either 2 or 3 racks;
- Small parts or screws can be held on different types of specific shelves;
- Other, specific means of storage are also in use, e.g., hanger-like storage for cables.

In the design of the line-side storage layout, various ergonomic and technical aspects have to be considered. The focus has to be placed on the assembly operators, letting them reach the required parts easily. Therefore, parts have to be placed as near as possible to the location where they are mounted into the car (point-of-assembly). The distances have to be considered in all three directions: horizontal, vertical, and left or right side of the line. In addition, each part has to be located within the range of the tools that are required for mounting it, such as lifts, electric screwdrivers, etc. Sufficient space has to be left clear for operator passage and various other objects that are required in the line-side area, such as toolboxes, desks, bins. Some of the latter objects are fixed, others are mobile, i.e., their placement can be modified according to the storage design.

In the manufacturing plant, border lines are replenished following several logical models: kanban logic for low rotation materials, direct flow by forklifts for high-rotation materials, and just-in-time logic for the car seats and the wheels. These logical replenishment models are well-known to and well-handled by advanced warehouse management systems.

Kitting as a new trend to manage parts:
Very recently the new tendency is to develop a new material handling concept that assists in transforming multi-part and component assembly tasks into organized and structured processes, helping to streamline operations for better efficiency and lower costs. It can also serve as a temporary storage rack keeping kitted parts in correct orientation, and as a quick visual aid to determine part inventories, sequencing and importantly, when the cart is empty, to make sure all components were assembled. The Kitting is ideal for use in the automotive and aerospace industries, or where kitting operations are prevalent. Utilizing the cart allows material handling technicians to accurately fill logistical orders, and optimize time by assembly staff to focus on added-value processes.

The Kitting has construction features, handling capabilities, sizing and flexibility that make it a perfect answer to the needs for assembly operations in a variety of applications.

At the moment, there is no well-known software solution for handling kitting. Tools developed in Net-WMS are featuring solutions for solving and handling such requirements. Handling kitting logic means a cooperation and integration of three technologies:

- Advanced visualisation to design structures of the kitting containers.
- Optimisation to configure the dimension of the kitting structures taking into account forms, sizes and constraints of the material.
- Virtual Reality and interaction with the optimisation tools to design the kitted parts.

Kitting structures might change every month (or even every week). Material used for building kitting can be seen as puzzles and can be adapted from one configuration to another. Warehouses in manufacturing require advanced and efficient tools to design a new kitting structure in a few hours. Such tools contribute to a better efficiency and lower cost.

The kitting operation might require advanced technologies like "Virtual Reality applied to packing problems in a WMS" to address the following issues:

- the 3D visualisation of the packed and packing objects allowing human operators to handle them "virtually";
- the interactive (i.e. real-time with respect to human perception) simulation of the laws of physics ruling these objects in order to "virtually rehearse" packing and unpacking operations, as well as to dynamically study the behaviour of container contents during shipping
- mixing the capabilities of optimisation and virtual reality to provide the most efficient assistance to the human packing planners;
- exploitation of the visualisation capabilities to design and to navigate in kitting structures.

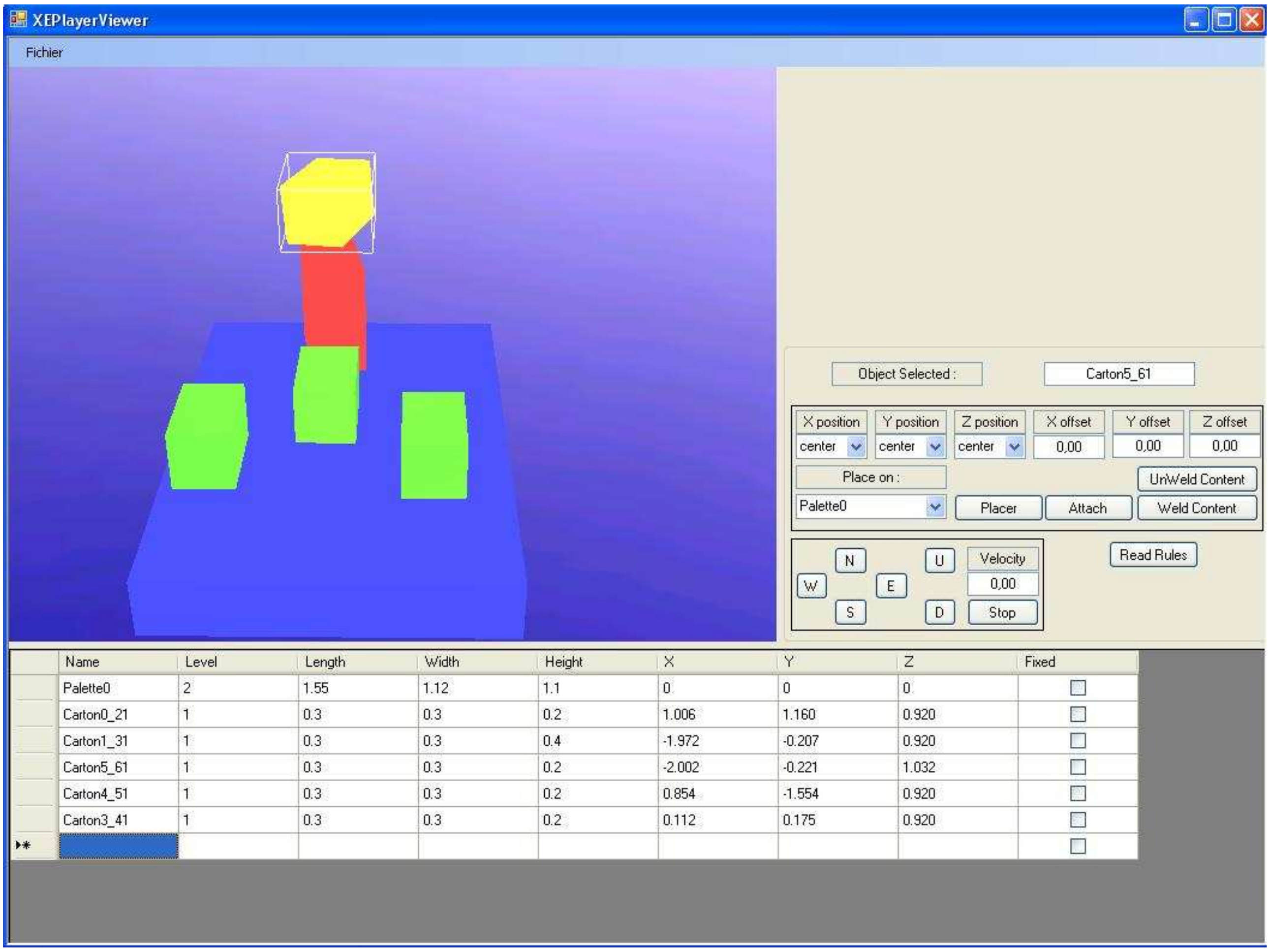

Figure 12: Design: Interactivity/Visualisation/Optimisation

For such requirements, one can anticipate the benefits of decision making tools for modern warehouses:

- The packing solver will reduce the cost of packing and of designing border lines.
- The online scheduler will reduce the cost of manpower and improve overall quality.
- Replenishment of stocks will benefit from scheduling activities in time.

3.10 Transport and Networked Warehouse management Systems

Optimisation of packing

Packing tools are essential to minimize the total linear meters of pallets. In fact, the packing tool will optimise each pallet whilst taking into account the warehouse constraints and articles constraints. For many warehouses, transport is externalised. The warehouse will communicate the total number of linear meters to load to transporters (virtual load).

Grouping constraints

In a warehouse, many operators take decisions on grouping customer orders depending on many parameters (same destination, same zone, …). In future WMS, such decision will be taken jointly by the WMS operator and the transporter manager. The transporter might want to group the transportation of pallets coming from several warehouses. Such requirements are additional constraints for the packing solvers.

Selection of the transporters

The competition between transporters is getting harder every year. Transporters are working with several WMSes by grouping several deliveries in order to propose attractive prices. Many software companies are investigating the development of sophisticated optimisation tools for the selection of a limited number of transporters satisfying the various and complex constraints of WMSes. Among these constraints one can find:

- The type of good to transport;
- The quantity to transport;
- The delivery date;
- The destination;
- The client open hours constraints;
- The reputation of the transporters;
- The minimal distance (a matrix of distances);
- The best costs (several matrix costs);
- …

Vehicle loading

Once the transporter is selected, the next task is to distribute the load over the vehicles of the transporter. Again, these are additional constraints for the packing optimisation tools. Possible cost savings are not yet precisely estimated.

Dispatching and Virtual Reality

Virtual Reality capabilities will provide means to visualise the content of the vehicle, collaborative work between the warehouse (node of the network) and the transporters (another node of the network). Transporters will have capabilities to visualise the pallets to transport from each WMS. Thus, it will be possible to optimise several loads from several input warehouses. Additionally, interactive simulation has the potential to validate that pallets are behaving properly during shipment, avoiding good damages.

Internet

Internet capabilities will offer possibilities to network all actors, from WMSes to transporters. It enables communication between several planning components across a network, ensuring that changes inflicted by a user or by recurrent events in one plan will propagate to the plans established in all other components.

A mobility interface will allow remote users (such as truck drivers) to report changes in the planning and to get answers for unexpected events.

4 Conclusion

This report described the important requirements of modern warehouses in terms of knowledge representation, sharing knowledge, connectivity, mobility, browser-based environments, designing packing models, computing the number of models to pack all items of an expedition, placement in the preparation zones, placement of packed items in vehicle according to the order of the visited customers, and planning and scheduling the packing activities in a WMS.

The report highlighted possible advanced tools and technologies for developing decision making solutions for modern warehouses. Optimisation, Virtual Reality, Knowledge Rules and Internet are key technologies for modern warehouses in term of reactivity, flexibility, robustness and cost efficiency.

5 Glossary

CKD: Completely Knocked Down
EDI: Electronic Data Interchange
ERP: Enterprise resource Planning
SCM: Supply Chain Management
SCP: Supply Chain Planning
SCE: Supply Chain Execution
MES: Manufacturing Execution System
WMS: Warehouse management System
TMS: Transport Management System
OMS: Order Management System
SOA: Services Oriented Architecture
J2EE: Java 2 Enterprise Edition
MOP: Means of Packing

6 References

A. Aggoun, E. Benazzi, M. Doussot, O. Gouasch, A. Lauer, A. Leverano, A. Kovacs : D.2.2 – *Case Studies*, Version 2, August 2007, Net-WMS project FP6-034691.

N. Beldiceanu and M. Carlsson and E. Poder and R. Sadek and C. Truchet. *A Generic Geometrical Constraint Kernel in Space and Time for Handling Polymorphic k-Dimensional Objects*, In Principles and Practice of Constraint Programming (CP'2007), LNCS vol. 4741, pages 180-194, Springer-Verlag.

Filipe Carvalho : *D8.1 : Networked architecture – J2EE compliant*, July 2007, net-WMS project FP6-034691.

F. Fages and all : D3.1. *State-of-the-art of enabling technologies for packing and planning in future WMS*, July 2007, Net-WMS project FP6-034691.

M. Journet et al. *Le Guide de la Logistique, Editions DALIAN*. 2005.

KLS LOGISTICS: *GILDAS WM, user manual* 2006.

J. Martin and F. Fages. *From business rules to constraint programs in wharehouse management systems*. In Proceedings of the 13th Conference on Principles and Practice of Constraint Programming CP'07, Lecture Notes in Computer Science, Providence, MA, USA, September 2007. Springer-Verlag.

F. Fages, S. Soliman, and R. Coolen. *CLPGUI: a generic graphical user interface for constraint logic programming*. Journal of Constraints, Special Issue on User-Interaction in Constraint Satisfaction, 9(4):241–262, October 2004.

Net-WMS : *Towards integrating Virtual Reality and optimisation techniques in a new generation of Networked businesesses in Warehouse management Systems under constraints*, FP6-034691.

M. Roux and Tong Liu. Optimisez votre plate-forme logistique, Editionsd'Organisation, *ISBN : 2-7081-3133-8*. 2004.

Sun Microsystems. *Simplified Guide to the Java 2 Platform, Enterprise Edition*. Sun Microsystems.