
Teaching Warehousing Concepts through Interactive Animations and 3-D Models

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Chapter 11

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CONTENTS

Abstract A significant challenge in teaching warehousing and facility logistics is conveying the important managerial and operational concepts to students effectively. These concepts always involve the presence and interactions of real-world objects such as facilities, vehicles, materials, storage and retrieval equipment, and most importantly humans. Meanwhile, knowledge in the mentioned fields does not only consist of concepts and principles but also includes algorithms that solve a variety of problems encountered in practice. Trying to communicate this body of knowledge in words with the help of photos and drawings frequently proves insufficient. In teaching his warehousing courses the author has realized that a set of educational media composed of interactive animations and virtual three-dimensional (3-D) models indeed facilitates the challenges described earlier.

Extensive educational media has been developed at Sabanci University in a coordinated effort of undergraduate students under the supervision of the author, and with the support of a multimedia expert. The media content has been selected and organized such that it can support and enrich classes and courses that would be based on two extremely useful books, one on implementing world-class practices in warehousing, and the other on strategies for saving space in the warehouse. The developed materials are freely available on the Internet to everyone, and are expected to contribute to the awareness, recognition, and growth of the fields of warehousing and facility logistics. In this chapter the educational materials developed, the rationale for the technology selections, and the teaching methods in class are explained. Meanwhile, resources for warehousing education are reviewed extensively and potential new technologies and approaches are highlighted.

11.1 Introduction

In a supply chain, physical products are delivered from their origin points (sources) to their destination points (sinks) through transshipment points. Warehouses are critical components within supply chains, because they may exist in all these three sets of points and significantly impact financial and service performance of supply chains. As of 1995, there were an estimated 550,000 warehouses in the United States alone (Andel, 1995). According to the Material Handling Industry of America (MHIA)*, an independent organization for warehousing professionals, ''the consumption of material handling and logistics equipment and systems in America exceeds $125 billion per year, and producers employ in excess of 700,000 workers.'' Thus the best education of warehousing professionals and the adequate design, implementation, and operation of warehouses may have a large positive impact on the economy.

The main goal of this chapter is to provide readers with new perspectives on teaching warehousing and material handling. For this purpose, firstly, existing resources for warehousing education are introduced and discussed. Next, a project carried out at Sabanci University, Istanbul, Turkey is presented. This continuing project has so far received contributions from 11 undergraduate students at Sabanci University, and aims at developing educational materials for warehousing. Until now, the project has involved the development of 31 animations that explain warehousing concepts, and 33 three-dimensional (3-D) models of warehousing equipment. Finally, other alternative technologies and approaches that can be used in warehousing education are proposed.

11.2 Resources for Warehousing Education

In this section, the various warehousing education resources available in-print and online are reviewed. These resources have been developed or their development has been supervised by professional organizations, publishers, software companies, or university professors. The resources are sorted, based on a subjective combined assessment of their quality, accessibility, online availability, cost, applicability, and relevancy to the work described in this chapter, as perceived by the author.

The book used as the textbook for the ''MS 420: Storage and Distribution Systems'' course at Sabanci University is *World-Class Warehousing and Material Handling* by Frazelle (2001). It is suggested that the book *How to Save Warehouse Space: 153 Tested Techniques*, published by Distribution Group† also be used in warehousing and supply-chain courses. The educational materials described in this chapter are designed to support these two books.

* http://www.mhia.org/

† http://www.distributiongroup.com/

MHIA* is a leading professional organization that serves warehousing and supply-chain community. The MHIA case studies Web page† contains brief case studies that summarize implementations of automated storage/retrieval systems (AS/RS) at companies and institutions in very diverse industries. Articles in the Material Handling Classics and Material Handling Perspectives sections within the MHIA Web site cover practically every aspect of warehousing and material handling. Material Handling Institute Bookstore‡ hosts an impressive collection of online books and articles, which can be downloaded free of charge through registration.

John J. Bartholdi at Georgia Institute of Technology$ has made available on his Web site a broad collection of educational materials for warehousing. The primary resource at Bartholdi's Web site is the freely downloadable online book *Warehouse & Distribution Science* by J.J. Bartholdi and S. Hackman. The book's Web site also contains abundant supplementary materials to support the book. These include software tools, past class projects with all their relevant materials (such as problem descriptions, plant layouts, and datasets), virtual tours of warehouses through photos and text explanations, and a compiled list of logistics news. One of the computational tools is the Java applet "Bird's Eye View" that visualizes a given location-based statistic within a given warehouse. The applet reads a Microsoft Excel spreadsheet that contains a map of the warehouse, with every spreadsheet cell representing a section of rack/shelving or empty space. The cells that represent physical storage locations should be labeled uniquely. The applet also reads a text file that contains the values for the statistic of interest for every storage location. Once the color scheme is selected, the applet displays a colored bird's eye view of a warehouse, where the storage locations are painted based on their values for the given statistic. Bartholdi's Web site also contains extensive information on bucket brigades, a method of organizing workers on an assembly line that results in self-balancing of the line.

College-Industry Council on Material Handling Education (CICMHE)‖ is a professional organization which "prepares and provides information, teaching materials and various events in support of material handling education and research." Educational resources available at the council's Web site include 16 case studies, 13 lecture resources, classroom modules, a list of textbooks, and a list of specialty sites with tools for warehousing/material-handling educators. The council also hosts the Material Handling

* http://www.mhia.org/
† http://www.mhia.org/et/et_case_studies.cfm
‡ http://www.mhiastore.org/
$ http://www2.isye.gatech.edu/people/faculty/John_Bartholdi/
‖ http://www.mhia.org/et/ET_MHI_CICMHE_Home.cfm

Taxonomy* Web pages that have been developed by Micheal G. Kay at North Carolina State University. These Web pages are available under Kay's own Web site,† as well. This very wide collection of Web pages provides taxonomy of material-handling equipment, accompanied with brief information for and pictures of every equipment.

Material Handling Multimedia Bank‡ is developed by Benoit Montreuil, Richard Legare, and Jonathan Bouchard at the Université Laval, Canada. The multimedia bank contains a rich collection of pictures and videos, besides application guides and information on vendor companies.

Another resource available on the Internet is the Interactive Warehouse$ a Java applet created by Kees Jan Roodbergen, a professor at Erasmus University. The Interactive Warehouse allows users to learn about algorithms for order-picker routing. The applet is based on an article by Roodbergen and De Koster (2001). The applet walks the user through the steps of setting a warehouse layout, creating an order, manually creating a route, running one of the known routing algorithms, and viewing the results.

Modern Materials Handling|| and *Logistics Management*# are two influential and valuable trade magazines that can be freely subscribed online (following an evaluation process). Once subscribed, one can read the full electronic versions of the magazine issues and can even download the issues in Adobe Acrobat (.pdf) format. Both magazines offer a wealth of information on warehousing, material handling, and supply-chain management.

Modern Materials Handling magazine has also made available online** several guideline documents that contain warehouse design plans and ideas. These guidelines have the following themes: Picking strategies, value-added services, world-class warehouse productivity, facility layouts for third-party logistics, and world-class facility layouts for e-commerce.

Distribution Group†† is a provider of useful practical information and news for distribution professionals around the world. Section 6 in this chapter describes the educational materials developed to support the book *How to Save Warehouse Space: 153 Tested Techniques* (Kuchta, 2004‡‡).

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* http://www.mhia.org/et/mhe_tax.htm
† http://www.ise.ncsu.edu/kay/mhetax/
‡ http://www.centor.ulaval.ca/mhmultimediabank/
$ http://www.roodbergen.com/warehouse/
|| http://www.mmh.com/
http://www.logisticsmgmt.com/
** http://www.contentconvergence.com/2001web/tocmain.htm
†† http://www.distributiongroup.com/
‡‡ http://www.distributiongroup.com/htsws.php

Dosch Design* is a software company that provides computer graphics products, including 3-D models, textures, visualizations, images, and movie clips for "license free" use by companies. The "Industrial Objects V2" product† created and marketed by the company contains 3-D models of industrial objects and equipment from workshop, factory, and warehouse environments. The 3-D models come in a variety of 3-D graphic formats and have very high quality. Many of the objects and equipment available in the mentioned product were not modeled within the scope of our project. Therefore, the usage of this product is suggested to support the educational materials described here. The company also offers the "Utility Vehicles" product,‡ which includes 3-D models of a truck, a trailer, and a forklift.

Jeroen van den Berg Consulting,$ is a consulting company in the Netherlands that specializes in warehousing and logistical information systems. The company's Web site contains several publications including management outlook reports and journal articles. Under the Research link at the Web site one can find WOLF, an online program for computing the suitability of ~50 warehouse management systems (WMS) for a given company. The system takes as input, answers to several questions, including region, number of warehousing staff, warehouse surface area, and order lines per day. Then a computational engine is run and the WMS products available in the WOLF database are ranked from most suitable to the least, accompanied with scores that denote their suitability. This is the only tool that was found on the Internet that provides such a decision-support capability. Many consulting companies sell research reports that provide similar information for a price in the scale of hundreds of U.S. dollars. Thus the WOLF tool is a highly useful example of decision support for technology and software selection.

The Progress Group‖ provides logistics and especially warehousing consultancy, and is based in Georgia, United States. The Publications link on the company's Web site leads to a compilation of insightful white papers and articles.

Tompkins Associates# is a warehousing and supply-chain consulting firm based in North Carolina, United States. The company Web site has a variety of publications available for download under the Publications link.

* http://www.doschdesign.com/
† http://www.doschdesign.com/products/3d/Industrial_Objects_V2.html
‡ http://www.doschdesign.com/products/3d/D3D_Utility_Vehicles.html
$ http://www.jvdbconsulting.com/
‖ http://www.theprogressgroup.com/
http://www.tompkinsinc.com/

These include “supply chain edge articles,” monographs, and white papers. The Tompkins Press books are also listed under the Publications link.

Armstrong & Associates Inc.[*] is a supply-chain market research and consulting firm based in Wisconsin, United States. The company has a listing of its guides and research reports on its Web site.[†]

Keck Virtual Factory Lab at Georgia Institute of Technology[‡] hosts two interactive tutorials on material-handling systems, one on AS/RS design and the other on “from-to-chart” analysis for product routings. The tutorials have been developed under the supervision of Gunter Sharp at Georgia Institute of Technology and Bala Ram at North Carolina A&T University.

Hkplanet.net Learning Center,[$] a portal created by HK Systems,[||] is provider of material-handling solutions for warehousing and manufacturing systems. This portal hosts a selection of industry articles and presentations from Material-Handling & Logistics Conferences. The Virtual Warehouse[#] that can be downloaded from this Web site can be interactively browsed through a joystick or mouse, and is a wonderful example of how virtual 3-D environments can be used for warehousing education. The HK Systems Web site also contains various resources, including white papers[**] and videos,[††] which can be used in teaching warehousing.

Heragu et al. (2003) report the development of a multimedia system for warehousing/material-handling classes. The system teaches ten principles of materials handling and three equipment categories. The system also depicts the industrial applications of some of the selected equipment in each of the three equipment categories and teaches quantitative methods for solving facility design and technology selection problems. The authors also present results of a formal evaluation of the system and its modules through surveys and interviews. They report that “an overwhelming number of students perceived their interaction with the modules to be a valuable experience.” The educational system is distributed on a compact disc with the title “10 Principles of Materials Handling” and can be purchased via the MHIA Store.[‡‡]

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* http://www.3plogistics.com/
† http://www.3plogistics.com/shopsite/index.html
‡ http://factory.isye.gatech.edu/mhs/
$ http://www.hkplanet.net/learning_center/
|| http://www.hksystems.com/
http://www.hkplanet.net/learning_center/virtual_warehouse.cfm
** http://www.hksystems.com/RESOURCES/whitepapers.cfm?m=4&s=1
†† http://www.hksystems.com/RESOURCES/multimedia.cfm?m=5&s=1
‡‡ http://www.mhiastore.org/

11.3 Selected Technologies and Teaching Approach

In this section, the selected technologies for creating the interactive animations and the virtual equipment models are explained. Then the teaching approach followed in class with the teaching materials is outlined.

11.3.1 Interactive Animations

Flash technology by Adobe* and the Adobe Flash authoring software have been selected in creating the interactive animations. Certain significant advantages of the Flash technology and Adobe Flash software played role in our selection include:

- The Flash animations (with file extension of .swf) that are created using Adobe Flash can be played from within almost any operating system. These animations can also be accessed over the Internet and be played within almost any Web browser that has a Flash Player add-in.
- A great percentage of Internet users already have Flash Player installed on their computers.
- The Flash animation files (with the .swf extension) have very small sizes, due to the use of vector graphics.
- The Adobe Corporation has a very strong presence on the Internet and a great influence in the software industry. The well-known Adobe Acrobat format (.pdf files) is the almost-universal document format in the academic and business world.
- The "action script" programming language within Macromedia Flash enables developers to create easy-to-use graphical user interfaces (GUI) and offers many of the capabilities of general-purpose programming languages, such as C^{++}.

In designing and implementing the animations, special attention was given to making sure that all the animations share the same user-interface elements: The same set of buttons, same set of font sizes, and the same height-to-weight ratios were used in all the animations. It is believed that this approach helps the users to perceive the animations developed by different people as components of an integrated whole.

11.3.2 3-D Models

The SolidWorks software was selected for developing the 3-D models of warehousing equipment. The main criteria that determined this selection

* http://www.adobe.com

were the ease of learning and the popularity of the software. The fact that SolidWorks software had been already well known by some of the students in the project also played an important role in our final decision.

11.3.3 Teaching Approach

The material described in this chapter has been used while teaching the "MS 420: Storage and Distribution Systems" course at Sabanci University in Spring 2006 semester. The course is offered to senior and junior students and has no prerequisites. The students have been exposed to the media related with Module 1 (World-Class Warehousing and Material Handling) twice throughout the class. The animations and 3-D models have been shown to the students by the instructor (the author of this chapter) as part of the lectures. Then, in a separate two-hour session, the students have been requested to bring their laptops to class with the Adobe Flash Player and SolidWorks Viewer software installed and the animations and the 3-D models downloaded. In this second exposure, the students interactively explored each of the animations and 3-D models in detail, while the instructor explained each of the concepts and equipment once again. The author believes that such an approach is much more robust in teaching the concepts and animations to students at a university where English is not the native language of the students. However, this hypothesis has to be tested through formal studies.

The animations in Module 2 (How to Save Warehouse Space) have been shown to students only once, in another two-hour hands-on session where the students interactively explored each of the Module 2 animations while listening to the instructor's explanations.

11.4 Related Work

One can find papers in engineering-education literature that present impressive animation-based educational materials in various fields of engineering. Leung et al. (2001) report the development and classroom use of an animated-simulation package to teach electromagnetic theory. Ong and Mannan (2002) describe a Web-based courseware to teach concepts and principles in metalworking, focusing on metallurgy aspects. Their system is developed using Adobe Flash (as in our work) together with Microsoft Front Page Web authoring system. Another system is developed by Ettouney et al. (2000) for the design and simulation of thermal desalination process. Their system has been used extensively in graduate, undergraduate, and training classes with great success.

One can also find examples of academic work where virtual 3-D models have been used: Ou et al. (2003) describe the implementation of a Web-based virtual reality system that facilitates teaching of computer-aided design (CAD).

11.5 Teaching World-Class Warehousing Concepts (Module 1)

For Module 1 of the educational materials, interactive animations and 3-D models have been developed for teaching warehousing concepts and material-handling equipment. This module is intended to support the book *World-Class Warehousing and Material Handling*.

11.5.1 Sample Animation 1: Order-Picking Schemes

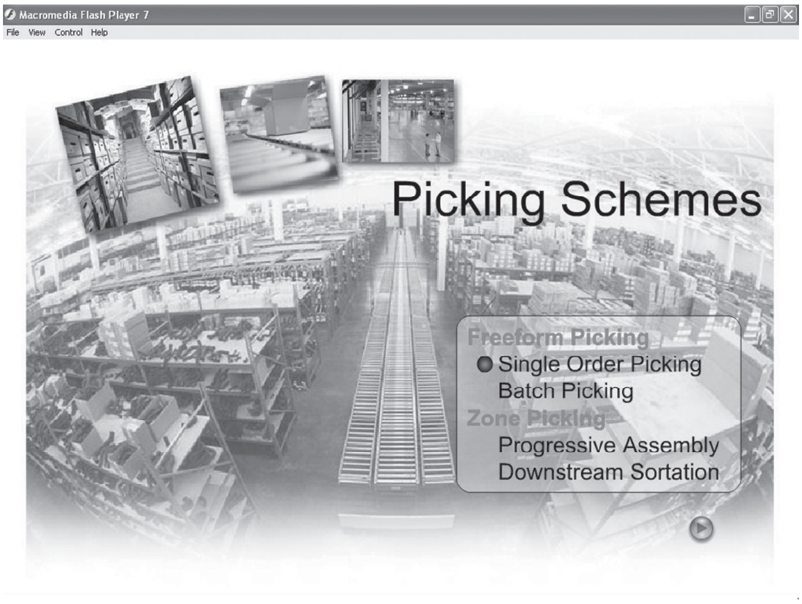
This animation summarizes the picking schemes in a warehouse, as explained in Frazelle (2001). Free-form picking takes place when there is no zoning in the warehouse. In this scenario, two possibilities are single-order picking and batch picking (Figure 11.1a). In single-order picking, the order picker travels on a new route to pick each new order (Figure 11.1b). In batch picking, the order picker picks two or more orders on the same route.

In zone picking, each order picker is allocated to a particular zone, and is responsible of picking the orders in his or her zone. Because the items within the same order may be picked at different zones simultaneously, there is a need to combine these picks into a single whole. Two strategies to achieve this are progressive assembly and downstream sortation. In progressive assembly, the first order picker picks the items in an order that reside in his or her zone, and puts the tote or box containing the incomplete order to the origin point for the second zone (Figure 11.1c). The next order picker seizes what the preceding order picker has accumulated and continues picking the items in the order that reside in his or her region.

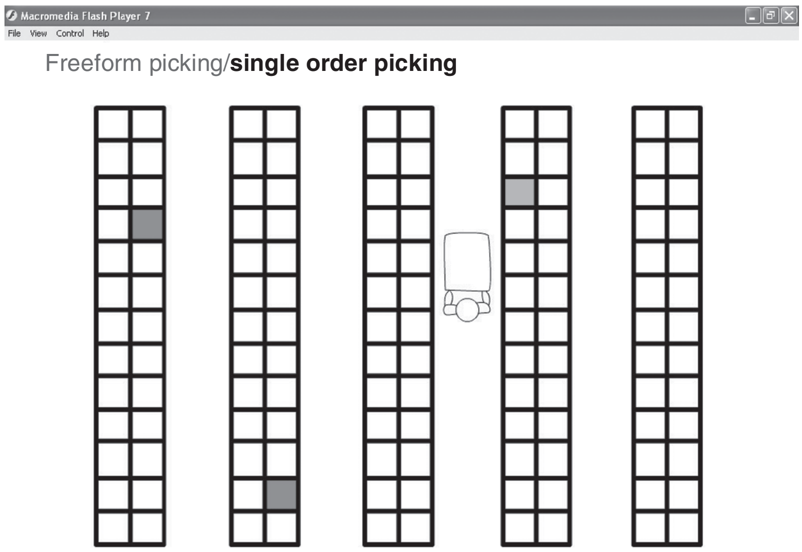
In downstream-sortation strategy, the order picker in each zone leaves the incomplete order, that he or she picked, into a conveyor, and the conveyor carries the totes or boxes to a sortation point (Figure 11.1d).

11.5.2 Sample Animation 2: Pick-to-Light System

Order picking in most warehouses involves minimal technology. A typical order-picking tour starts with receipt of a picking list, which displays



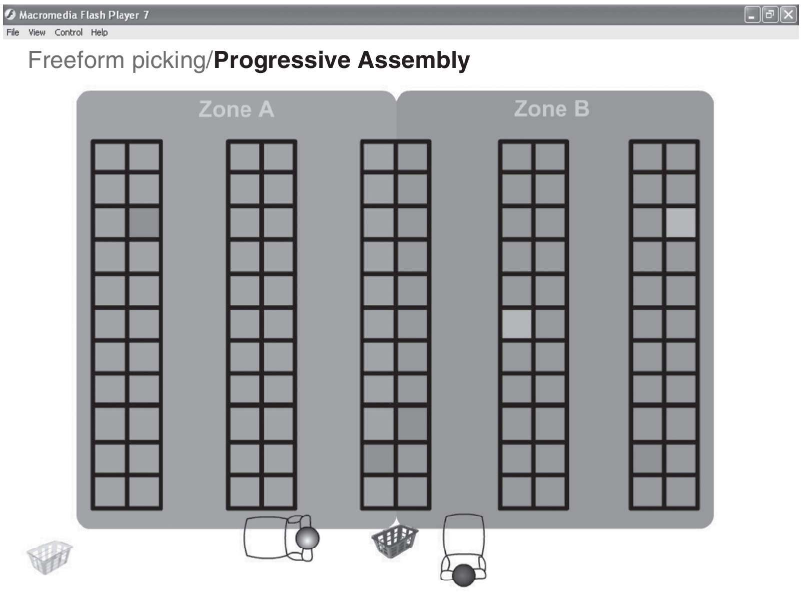
(a)



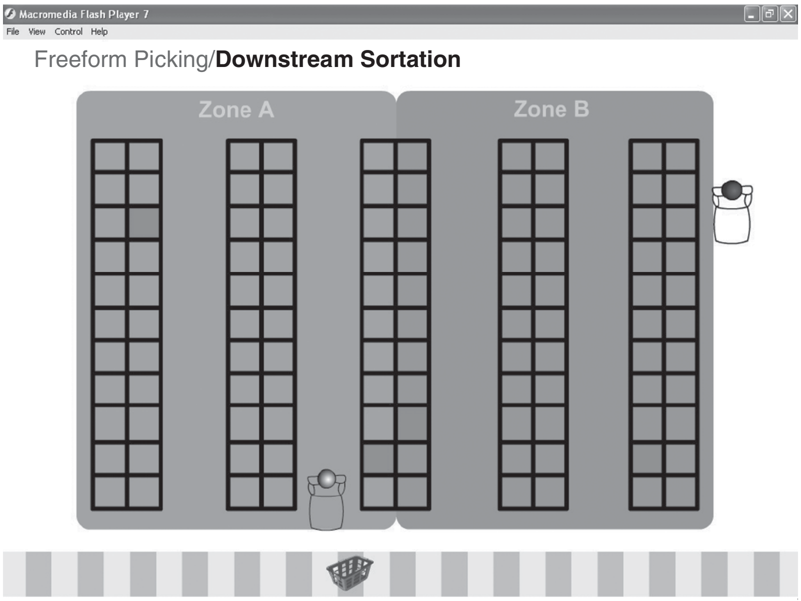
(b)

Figure 11.1 Animation for illustrating picking schemes in a warehouse.

(continued)



(c)



(d)

Figure 11.1 (continued)

the item number (also referred to as stock-keeping unit (SKU) number), the item location, and the number of units to pick. The order picker sorts the items to be picked in his or her mind, and then visits each item's location to make the picks (Figure 11.2a). Tasks that consume time during this classical mode of order picking are traveling, searching, extracting, and documenting.

One problem encountered in most order-picking operations is the erroneous picking of items. A pick-to-light system is a solution that technology offers to reduce the times for the mentioned tasks and to reduce order-picking errors (Figure 11.2b). In a pick-to-light system, an indicator light and an electronic numeric display inform the order picker on where to pick from and in what quantity. The order picker is relieved from the burden of searching the item locations and—to a degree—relieved from other tasks. Picking errors are also observed to decrease when pick-to-light systems are implemented. Thus the pick-to-light system is a viable option that can reduce costs and increase order-picking accuracy in a warehouse.

In this animation, the user is expected to pick two separate orders, first from storage locations without any pick-to-light systems and second from

(a)

Figure 11.2 Pick-to-light system animation.

(continued)

(b)

Figure 11.2 (continued)

storage locations with pick-to-light systems. Even though the user is given pick lists in both scenarios, order picking is greatly facilitated by the pick-to-light systems in the second scenario. Thus the user experiences firsthand the benefits of pick-to-light systems.

11.5.3 Sample 3-D Model

Figure 11.3 illustrates the 3-D model for automated item-dispensing machine, as viewed from within a Web browser. It is required to install the SolidWorks Viewer software beforehand to be able to view the 3-D models.

The automated item-dispensing machine is also referred to as A-frame, because it is composed of two rows of dispensers positioned in the form of the letter A, with a belt conveyor running underneath. The information regarding the items to be picked (dispensed) is communicated to the A-frame and the dispensers automatically kick the bottommost packages of the items to be picked onto the conveyor. Workers continuously feed the dispensers with items picked from other systems such as the gravity

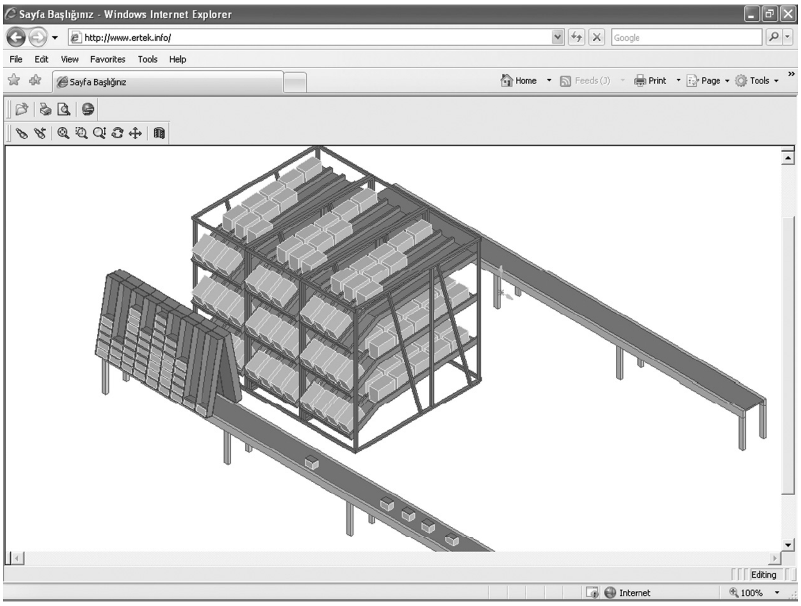


Figure 11.3 3-D model for automated item-dispensing machine (A-frame).

flow rack (as in Figure 11.3). Pick (dispensing) rates with the A-frame can reach up to 2000 picks per hour. The A-frame is especially applicable in industries which require "high throughput of small items with uniform size and shape" (Frazelle, 2001). One can find this equipment being used in warehouses from which cosmetics, wholesale drugs, compact discs, and publications are distributed.

Once the 3-D model is opened from within a browser, the user is able to interactively explore the equipment model. Zooming, panning, and rotating are some of the ways in which the user can interact with the model. These actions enable the user to focus on details, focus at specific sections of the equipment, and to observe the model from the best viewing angle.

11.6 Teaching How to Save Warehouse Space (Module 2)

In this section, a sample animation is explained from Module 2, "How to Save Warehouse Space." The animation illustrates Idea 72 suggested by

Kuchta (2004). It should be noted that some of the animations in Module 2 reflect the ideas presented in the *Modern Materials Handling* magazine (MMH, 2004).

11.6.1 Sample Animation 3

Figure 11.4 illustrates how to save warehouse space through providing bridges over cross-aisles. Figure 11.4a shows a storage block without any cross-aisles, which frequently requires the order picker to detour around the storage block. This causes wasted time during order picking. The classic solution to remedy this problem is to establish a cross-aisle that provides a quick pass way from one side of the storage block to the other side. However, cross-aisles are frequently implemented so as to consume the whole vertical space, resulting in loss of storage space. The solution is to provide bridges over cross-aisles as in Figure 11.4, which enables the reclamation of otherwise-lost vertical space.

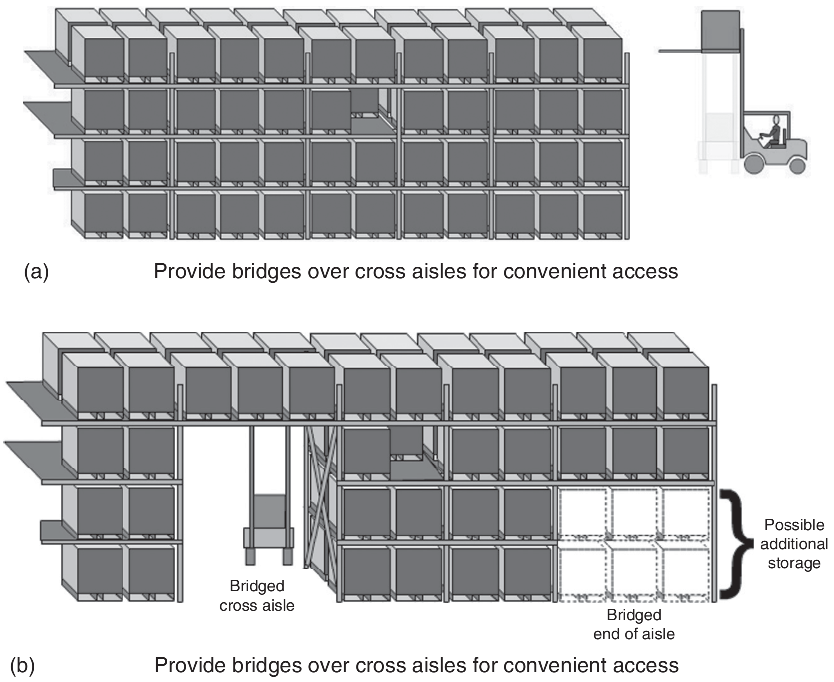


Figure 11.4 Animation showing how to save warehouse space through providing bridges over cross-aisles.

11.7 Other Possible Technologies and Approaches

In this section some of the other possible technologies and approaches, which can be applied in developing warehousing course materials, are discussed.

11.7.1 3-D Virtual Warehouses

Instructors can develop or contribute to the development of 3-D virtual environments that simulate real-world warehouses. These virtual environments can be created using simulation software with 3-D visualization capabilities, such as Automod.[*] Simulation models of warehousing systems have been used to teach simulation (Standridge, 2000), and can as well be used for teaching warehousing concepts. One can also build the virtual warehouses using 3-D visualization and animation software libraries or game engines.[†,‡] Developers of such learning environments can learn a great deal from practices of high-profile companies that provide learning solutions with interactive 3-D graphics. One such company is 3-Dsolve.[$] The company provides software platforms for collaborative simulation-based training, including implementations through the open-source Croquet operating system.[||]

Another way to construct virtual warehouses is to take 3-D photos or film 3-D videos[#] and show them to the students as they wear 3-D glasses. These pictures and videos, seen through 3-D glasses, give the feeling of observing the real world. Many Hollywood films, including titles such as *Shrek* and *Spy Kids 3D Game Over* are available as 3-D movies and come with 3-D glasses for home entertainment. In the mean time, many technology companies including Philips, Mitsubishi Electric, and IBM have already developed prototypes for three-dimensional television (3-D TV), which will revolutionize the electronics, media, and entertainment industries. These televisions enable viewing of high-resolution 3-D content with bare eyes, without the need for any special apparatus such as 3-D glasses. Creating 3-D warehousing-education content for these televisions may greatly contribute to the recognition and advancement of the field of warehousing.

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* http://www.brookssoftware.com/
† http://en.wikipedia.org/wiki/Game_engine
‡ http://www.devmaster.net/engines/
$ http://www.3dsolve.com/
|| http://www.opencroquet.org/
http://www.whurl.net/pages/3dgallery.php

11.7.2 360° Panoramic Scenes

Virtual warehouses can also be created through immersive 360° panoramic scenes. A panoramic scene is constructed through stitching together a series of images covering the 360° surrounding view using specialized software.[*, †, ‡] Some panorama software products enable establishing hyperlinks to other scenes through hot spots within a given scene. In using this technology one can create a multitude of 360° scenes within a warehouse and can thus provide the users a virtual tour of the facility.

11.7.3 Media-Enhanced Case Studies

Supply-chain management classes typically involve discussion and assignment of business case studies. Implementation of these case studies can significantly be enhanced by describing the problems using animations and 3-D virtual worlds. Case studies covering supply-chain management and warehousing can be found in various textbooks, two of which are by Dornier et al. (1998) and by Simchi-Levi et al. (2002). Some of the cases in these books are from the Harvard Business School (HBS) Cases collection,[$] the richest source of business cases in the world. Two case studies from the HBS Cases collection that are especially suitable for adopting in warehousing classes are the following:

- "Amazon.com's *European Distribution Strategy*," by Janice Hammond, HBS Cases no: 9-605-002
- "*Velky Potraviny: Prague*," by William Coyle and Jay Rao, HBS Cases no: BAB013

It is proposed that the discussion of the above two cases and other relevant cases can be enhanced through educational media described earlier.

11.7.4 Software Demonstration Videos

Discussion and teaching of software tools are major contributors to the quality and usefulness of a warehousing course. It is suggested that instructors

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* http://www.ulead.com/cool360/

† http://www.360dof.com/

‡ http://www.easypano.com

$ http://www.hbsp.harvard.edu/b01/en/cases/cases_home.jhtml develop, contribute to the development of, or at least use software demonstration videos for teaching various software tools that are used in warehouse planning, design, and management. Software packages that can be taught include WMS, decision-support software, spreadsheets, databases, and modeling environments for simulation and optimization of warehousing systems. The software demonstration videos are created by first capturing the on-screen actions and recording any audio input as the user performs actions, editing the captured screens and audio, and then finally publishing the resulting videos in popular multimedia or video formats, such as .avi and .swf (Adobe Flash animation format), respectively. Once a software demonstration is recorded, it is also possible to enhance it by adding captions, images, buttons, and highlights. One highly capable commercial package that enables creation of software demonstration videos is Adobe Captivate.* DemoCharge† is an alternative commercial package for creating such videos: DemoCharge is available at a lower price and has the advantage of creating videos in various formats, including Java applets. However it falls behind Adobe Captivate with respect to editing of captured screen actions and incorporating other media (such as Adobe Flash animations) into the software demonstrations. The author has found this video-based method to be much more superior in teaching software applications when compared to other approaches, such as static tutorial documents.

11.8 Conclusions

This chapter presented existing resources, some newly developed resources used at Sabanci University, and alternative technologies and approaches for teaching warehousing and material handling.

The educational materials described in this chapter have been made freely available on the Internet through the MIT License.‡ They can be accessed through the Free Information Fountain link at http://www.ertek.info. The MIT License gives complete freedom to anyone to use the material in any way he or she likes, subject to the condition that the authors will not be held liable in any way from any unfavorable situations that might arise. This license was selected because it was found to be the most "freedom-granting" software license among those approved by the Open Source Initiative.$

* http://www.adobe.com/products/captivate/
† http://www.yessoftware.com/
‡ http://opensource.org/licenses/mit-license.html
$ http://www.opensource.org/licenses/

11.9 Future Work

One future path to improve the educational material described here is to convert the developed 3-D models to other file formats so that they can be embedded into simulation software products with 3-D animation capability, such as Automod, Arena, Promodel, Quest, and Taylor II. For example, the Automod software* supports importing of the VRML (.wrl), Open Inventor (.iv), 3D Studio (.3ds), AutoCAD (.dxf), and LightWave (.lwo) 3-D graphic formats (*Automod 11.0 User's Guide*, 2003). However the models developed in our project are currently available in SolidWorks graphic format and have to be converted to one of the mentioned formats and tested. This may be a very time-consuming task, because our trials to convert the models to VRML format from within SolidWorks resulted in unsatisfactory output.

Another future work is converting the models into 3-D graphic file formats which enable them to be embedded directly into Web pages, without having to install special viewer programs. One notable company that provides the technology for such functionality is Demicron,† which provides the software that enables Web-based interaction with 3-D models from within Java applets.

Enhancing the interactive animations through real-world videos, better graphics, and better user interfaces, and implementing the technologies discussed in Section 11.7 are yet other possibilities for future work.

One important consideration for those building e-learning environments is to conform to well-established specifications and standards, such as shareable content object reference model (SCORM).‡ Unfortunately, the e-learning materials reported in this chapter were not developed in conformance with any such standards. Revising the developed materials and the general structure of the learning modules according to one of the well-accepted standards is hence another possible area for future work.

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* http://www.brookssoftware.com/
† http://www.demicron.com/
‡ http://www.adlnet.gov/scorm/

the design of the interactive animations. And finally, the author thanks Sabanci University undergraduate students Hakan Kelelioğlu and Umut Karaarslan for their guidance in selecting the most "freedom-granting" license, namely the MIT license, before making the educational materials available on the Internet.

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