CIRRELT

Centre interuniversitaire de recherche
sur les réseaux d'entreprise, la logistique et le transport

Interuniversity Research Centre
on Enterprise Networks, Logistics and Transportation

Selection of Material Handling and Warehousing Equipment: Data Analysis Process and Statistics

Moustapha Ahmed Bouh
Diane Riopel

October 2016

CIRRELT-2016-53

Bureaux de Montréal :
Université de Montréal
Pavillon André-Aisenstadt
C.P. 6128, succursale Centre-ville
Montréal (Québec)
Canada H3C 3J7
Téléphone : 514 343-7575
Télécopie : 514 343-7121

Bureaux de Québec :
Université Laval
Pavillon Palasis-Prince
2325, de la Terrasse, bureau 2642
Québec (Québec)
Canada G1V 0A6
Téléphone : 418 656-2073
Télécopie : 418 656-2624

www.cirrelt.ca

Selection of Material Handling and Warehousing Equipment: Data Analysis Process and Statistics

Moustapha Ahmed Bouh*, Diane Riopel*

Interuniversity Research Centre on Enterprise Networks, Logistics and Transportation (CIRRELT) and Department of Mathematics and Industrial Engineering, Polytechnique Montréal, P.O. Box 6079, Station Centre-Ville, Montréal, Canada H3C 3A7

Abstract. This work completes the previous technical report Ahmed Bouh and Riopel (2015). It describes the analysis of data used in the papers treating the selection problem of material handling and warehousing equipment. It also presents the process of obtaining the new classifications of material handling equipment and attributes presented in the mentioned technical report. The number of papers of the literature increased from 27 to 30 with the latest published ones.

Keywords. Material handling equipment, warehousing equipment, attribute, statistics, process of classification.

Acknowledgment. This research project has received financial support from the grant program to the discovery of the Natural Sciences and Engineering Research Council of Canada (NSERC). This support is greatly appreciated.

---

* Corresponding authors: Moustapha.AhmedBouh@cirrelt.ca
Diane.Riopel@cirrelt.ca

Dépôt légal – Bibliothèque et Archives nationales du Québec,
Bibliothèque et Archives Canada, 2016

1. Introduction

The contemporary research in selection problem of material handling equipment (MHE) and warehousing equipment (WE) has started publishing three decades ago or more. The problem is a set of collected data with a selection methodology to be developed. The number of collected papers in the literature increased to 30 papers adding the latest publications. The previous published technical reports on selection of material handling and warehousing equipment cited 27 papers. The technical report Ahmed Bouh and Riopel (2015) has presented new classifications of MHE and attributes. They could be used in the upcoming research works on MHE selection.

This work completes the mentioned technical report. It describes the process conducted to obtain the new classifications. It also presents transversal statistics of the data used in the literature of Table 1. The data are MHE, WE and attributes. Each data is analysed separately and respectively in the same order. Tables and commentaries are provided.

Table 1: The used literature

Paper number	Authors (date)
1	Ahmed and Lam (2014)
2	Bookbinder and Gervais (1992)
3	Chakraborty and Banik (2006)
4	Chan, Ip, and Lau (2001)
5	Cho and Egbelu (2005)
6	Chu, Egbelu, and Wu (1995)
7	Fisher, Farber, and Kay (1988)
8	Fonseca, Uppal, and Greene (2004)
9	Gabbert and Brown (1989)
10	Hadi-Vencheh and Mohamadghasemi (2015)
11	Hassan, Hogg, and Smith (1985)
12	Hassan (2010)
13	Hassan (2014)
14	Karande and Chakraborty (2013)
15	Kim and Eom (1997)
16	Kulak (2005)
17	Malmborg, Krishnakumar, Simons, and Agee (1989)
18	Maniya and Bhatt (2011)
19	Matson, Mellichamph, and Swaminathan (1992)
20	Mirhosseyni and Webb (2009)
21	Onut, Kara, and Mert (2009)
22	Park (1996)
23	Sharp et al. (2001)
24	Telek (2013)
25	Trevino, Hurley, Clincy, and Jang (1991)
26	Tuzkaya, Gülsün, Kahraman, and Özgen (2010)
27	Ustundag (2014)
28	Velury and Kennedy (1992)
29	Welgama and Gibson (1995)
30	Yaman (2001)

2. Material handling equipment

2.1. Material handling equipment analysis process

The technical report Ahmed Bouh and Riopel (2015) introduced new classification of MHE. After harmonisation, the MHE used in the papers are grouped in seven categories defined in Table 2.

Table 2: MHE categories

Name	Description	Source
Manual	Operated by people without MHE	Institute of Industrial Engineers (2000)
Unit load conveyor (ULC)	'Horizontal, inclined or vertical device for moving or transporting packages or objects in a path predetermined by the design of the device and having points of loading and discharge fixed, or selective'	Institute of Industrial Engineers (2000)
Bulk load conveyor (BLC)	Equipment as the unit load conveyor but adapted for products which are generally shipped in volume such as liquids, ore, or grain	Institute of Industrial Engineers (2000)
Hoist (H)	'Mechanism for lifting and lowering loads'	Institute of Industrial Engineers (2000)
Industrial truck (IT)	'Wheeled vehicle, primarily for the movement of objects or materials, and usually associated with warehousing, but not including vehicles intended primarily for earth-moving or over-the-road hauling.'	Institute of Industrial Engineers (2000)
Automated guided vehicle system (AGVS)	'Self-controlled vehicle that follows specified paths in a plant floor to move material, most systems are directed (guided) through a set of predefined (fixed) paths, new guidance systems can plan paths and control the vehicle dynamically.'	Institute of Industrial Engineers (2000)
Robot (R)	'Robot is a reprogrammable, multifunctional manipulator designed to move material, parts, tools, or specialised devices through variable programmed motions for the performance of a variety of tasks.'	Institute of Industrial Engineers (2000)
Pipe line (PL)	'Channel of support or a specific portion thereof by means of which materiel flow from sources or procurement to their point of use.'	Public Works and Government Services Canada (2015)

Table 3 describes the process of transformation in order to move from all the different classifications used in each paper to a common classification of seven groups. The seven groups are called categories. Each category has classes. Each class has types and under the types there are models. The models are not considered in this research. The selection is made between MHE types.

Some papers do not specify the used MHE; others have not classified them or have several groups of MHE.

The first column contains the number of the paper according to Table 1. The second column contains the name of the groups and the quantity of MHE for each group. The same names used in the papers are kept. The acronyms of Table 2 are used. When the data are not clear or missing, the table describes the case. The third column divided in seven sub-column presents the MHE under the new classification. The fourth column contains remarks describing the changes. When it is written in parentheses (4 to 4) it means the initially cited amount of equipments in the respective paper was 4 and our classification considers as well all the four equipments, so no changes. If a change is made, it means the number has changed in the new classification for some reason as explained for each paper. For instance, "Changes (50 to 51)". In this case, jib crane and gantry crane were specified together as one MHE type but they are different as considered in Cho et al. (2005). In the new classification, instead of 50 MHE types we consider 51 types.

Table 3: Before and after the new classification of MHE

Paper number	Before	After							Remarks
		ULC	BLC	H	IT	AGVS	R	PL	
1	No classified. 4 alternatives. Use a category as an equipment type.	1			3				No changes (4 to 4).
2	Conveyor (14); Crane & Hoist (7); IT (8).	14		7	8				No changes (29 to 29).
3	Three categories (conveyor, hoist, industrial truck) and one undefined auxiliary equipment (A1 to A4).								
4	Conveyors (14); Overhead conveyors (3); Cranes (5); IT (16); AGVS (8); Robots (4); Storage/retrieval systems (11).	17		6	16	8	4		Changes (50 to 51). Jib crane and gantry crane were specified as together but they are different as considered in Cho et al. (2005). Storage and retrieval S/R systems are ignored.
5	MHE Movement: Industrial vehicle (6); AGV (3); Monorail (1); Gravity conveyor (4); Above floor conveyor (7); Overhead conveyor (2); Crane (5); MHE Positioning (5); MHE Storage: Automated storage and retrieval systems AS/RS (3); Rack system (4).	13		6	6	3			Changes (28 to 28). Roller conveyor is repeated twice as gravity conveyor and above floor conveyor. Positioning equipment and Storage equipment are ignored.
6	Conveyors (12); Monorail and cranes (5); Industrial vehicles (15); No	12		5	10	5			No changes. AGVS are cited as industrial vehicles.

Paper number	Before	After ULC	BLC	H	IT	AGVS	R	PL	Remarks
	equipment (1 manual). Other equipments are cited.								
7	No classified equipment. 23 MHE. Manual and Not manual are cited.	9		3	6	4			No changes (22 to 22).
8	ULC (20, 6 classes); Sortation conveyors (10); Monorail systems (4); BLC (33, 7 classes)	20	33	4					Changes (67 to 57). Sortation conveyors (10) are ignored.
9	Missing MHE information. The methodology is described.								
10	ULC (5)	5							No changes (5 to 5).
11	Four undefined application examples from Webster, D. B. (1969).								
12	Undefined application example from Maloney, D. (2002).								
13	Missing MHE information. Missing attribute information. The input and the output of ten expert systems are compared.								
14	Four undefined MHE alternatives (A1 to A4).								
15	Unclear application example (combined systems of MHE with warehousing systems).								
16	IT (11); ULC (14); AVG (7); Cranes (4); S/R systems (6); R (4).	14		4	11	7	4		No changes. S/R systems are neglected as MHE.
17	IT (16). AGVS (as category).				16	1			No changes (17 to 17).
18	Eight undefined alternatives (A1 to A8).								
19	AGV (4); ULC (Gravity, Powered: 12); H (6); IT (8).	12		6	8	4			No changes. Differences on equipment names.
20	IT (10); Floor conveyors (6); Overhead conveyors (3); AGV (4); Cranes (3).	9		3	10	4			No changes (26 to 26).
21	Three categories (conveyor, industrial truck, AGVS) and two hoist types (fixed crane and rail system crane) (A1 to A5).								
22	Pipe (1); Gravity ULC (3); Floor powered conveyor (9); Overhead powered conveyor (3); IT (13); Monorail (1); AGV (5); Robot (4); Crane (4).	15		5	13	5	4	1	No changes (43 to 43). Use a pipe line.
23	Analysis of some MHE classes mentioned as needed.								
24	Missing information.								
25	IT (5)				5				No changes (5 to 5).
26	Six undefined alternatives of industrial truck category (IT1 to IT6).								
27	Two undefined MHE alternatives (MH1 and MH2).								
28	Unclear application example (combined systems of MHE with transportation systems).								
29	IT (4 forklifts, 1 tow-tractor); H (2 gantry cranes, 3 bridge cranes, 1 mobile crane); AGV (1); ULC (4).	4		3	2	1			Changes. Undefined equipment is used.
30	Six classes and categories (robot, AGVS, RGVS, gantry, forklift, conveyor).								

2.2 Material handling equipment statistics

The following tables (Table 4 to Table 10) present the details about considered MHE in the papers and how many times each one is cited in the research. It contains seven lists of MHE.

Some papers are mentioning **MHE categories** instead of types. They are written in bold. Some others use *MHE classes*. They are written in *italic*.

MHE names are harmonised when they are called with similar names in different papers. For instance, the equipment Tugged AGV (AGVS 22) is called in some papers either Tugged AGV or Tugger AGV.

Some MHE are called with synonyms in the papers. For instance, the synonyms of the equipment AGV towing vehicle (Tompkins, White, Bozer, & Tanchoco, 2010) are Tractor AGV (AGVS 20), Tractor train AGV (AGVS 21) and Tugged AGV (AGVS 22). They are all presented separately.

As mentionned in Ahmed Bouh and Riopel (2015), some related equipment and accessories (grippers, identification and communication devices, manipulators, sortation systems, racks and unit loads) are used in some papers.

The first columns of the tables contain acronyms with a number referencing each MHE type. The second columns contain the name of the MHE types. The third columns contain the numbers of the papers citing the MHE type. The fourth columns present the citation frequencies of each MHE type.

Table 4: Unit load conveyor (ULC)

ULC number	Name	Paper number	Total
ULC 1	Apron conveyor	2; 4	2
ULC 2	Arm conveyor	8	1
ULC 3	Ball-Top conveyor	5	1
ULC 4	*Belt conveyor*	2; 5; 6; 16; 22	5
ULC 5	Belt driven roller conveyor	8	1
ULC 6	*Bucket conveyor*	2; 16; 22	3
ULC 7	Cart-on-track conveyor	5; 6; 16; 19; 22	5
ULC 8	*Chain conveyor*	2; 5; 6; 16; 20; 22; 29	7
ULC 9	Chain driven roller conveyor	8	1
ULC 10	Chain operated overhead conveyor	4; 20	2
ULC 11	Chain-on-edge conveyor	8	1
ULC 12	Chute conveyor	2; 4; 5; 6; 8; 10; 16; 19; 22	9
ULC 13	Continuous vertical conveyor	4; 8	2
ULC 14	**Conveyor**	1; 21	2
ULC 15	Drag chain conveyor	8	1
ULC 16	Flat top chain conveyor	8	1
ULC 17	Flat-belt conveyor	4; 10; 20	3
ULC 18	Flight conveyor	2	1
ULC 19	Flush tow conveyor	8	1

ULC number	Name	Paper number	Total
ULC 20	Gravity roller conveyor	4; 5; 7; 8; 19; 20; 22	7
ULC 21	Gravity wheel conveyor	20; 22	2
ULC 22	Gravity-bucket conveyor	4	1
ULC 23	In-floor towline conveyor	19	1
ULC 24	Inverted power & free conveyor	19	1
ULC 25	Line shaft roller conveyor	8	1
ULC 26	Live chain-roller conveyor	7	1
ULC 27	Live roller conveyor	7	1
ULC 28	Opposed shelf conveyor	8	1
ULC 29	Overhead monorail conveyor	16	1
ULC 30	Overhead tow conveyor	8	1
ULC 31	Plain chain conveyor	16	1
ULC 32	Pneumatic conveyor	2; 4; 6; 10; 22	5
ULC 33	Pneumatic tube conveyor	16	1
ULC 34	Power & free conveyor	2; 4; 5; 6; 7; 19; 20; 22	8
ULC 35	Powered belt conveyor	19	1
ULC 36	Powered chain conveyor	19	1
ULC 37	Powered overhead trolley	19	1
ULC 38	Powered roller conveyor	4; 19; 20	3
ULC 39	Reciprocating conveyor	8	1
ULC 40	Roller bed belt conveyor	8	1
ULC 41	*Roller conveyor*	2; 5; 6; 10; 16; 22; 29	7
ULC 42	Screw conveyor	2; 4; 16; 22	4
ULC 43	Self-powered monorail conveyor	4; 7; 20	3
ULC 44	Skate wheel conveyor	5	1
ULC 45	Skatewheel gravity conveyor	7; 8	2
ULC 46	Slat chain conveyor	8	1
ULC 47	*Slat conveyor*	2; 4; 5; 6; 7; 16; 19; 20; 22; 29	10
ULC 48	Slider bed belt conveyor	8	1
ULC 49	Tow conveyor	2; 5; 6; 7; 16; 22; 29	7
ULC 50	Trash belt conveyor	8	1
ULC 51	Trolley conveyor	5; 6; 7; 16; 22	5
ULC 52	Troughed-belt conveyor	4	1
ULC 53	Underfloor tow conveyor	8	1
ULC 54	Vertical reciprocating conveyor	4	1
ULC 55	*Vibrating conveyor*	2; 4; 6; 22	4
ULC 56	*Wheel conveyor*	2; 4; 5; 6; 10; 16; 19	7

Table 5: Bulk load conveyor (BLC)

BLC number	Name	Paper number	Total
BLC 1	Belt type centrifugal discharge bucket elevator	8	1
BLC 2	Belt type continuous discharge elevator	8	1
BLC 3	Chain type centrifugal discharge bucket elevator	8	1
BLC 4	Chain type continuous discharge bucket elevator	8	1
BLC 5	Deep pan apron chain conveyor	8	1
BLC 6	Dilute phase system conveyor	8	1

BLC number	Name	Paper number	Total
BLC 7	Enmasse conveyor	8	1
BLC 8	Fan type system conveyor	8	1
BLC 9	Flight conveyor	8	1
BLC 10	Gravity discharge bucket conveyor	8	1
BLC 11	Hooper loader shaft less conveyor	8	1
BLC 12	Internal discharge elevator	8	1
BLC 13	Mobile stripper conveyor	8	1
BLC 14	Pivoted bucket conveyor	8	1
BLC 15	Portable vacuum pressure system conveyor	8	1
BLC 16	Positive discharge elevator	8	1
BLC 17	Pressure dense phase system conveyor	8	1
BLC 18	Rubber belt grade 1 conveyor	8	1
BLC 19	Rubber belt grade 2 conveyor	8	1
BLC 20	Rubber belt grade 3 conveyor	8	1
BLC 21	Shallow pan apron chain conveyor	8	1
BLC 22	*Slat conveyor*	8	1
BLC 23	Sliding conveyor	8	1
BLC 24	Stationary stripper conveyor	8	1
BLC 25	Super capacity bucket style F elevator	8	1
BLC 26	Super capacity bucket style G elevator	8	1
BLC 27	Super capacity bucket style H/HL elevator	8	1
BLC 28	Troughed and shafted conveyor	8	1
BLC 29	Troughed and shaft less conveyor	8	1
BLC 30	Tubular and shafted conveyor	8	1
BLC 31	Tubular and shaft less conveyor	8	1
BLC 32	Vacuum dense phase system conveyor	8	1
BLC 33	*Vibrating conveyor*	8	1

Table 6: Hoist (H)

H number	Name	Paper number	Total
H 1	Automated electrified monorail system	8	1
H 2	Bridge crane	2; 4; 5; 6; 7; 19; 20; 22; 29	9
H 3	Electric monorail system EMS	5	1
H 4	Fixed crane	21	1
H 5	Gantry crane	2; 4; 5; 6; 7; 16; 19; 20; 22; 29; 30	11
H 6	Hand pushed monorail	19	1
H 7	Heavy-duty monorail	19	1
H 8	**Hoist**	2; 5; 19	3
H 9	Inverted power and free monorail system	8	1
H 10	Jib crane	2; 4; 5; 6; 16; 19; 20; 22	8
H 11	Light-duty monorail	19	1
H 12	Mobile crane	2; 4; 29	3
H 13	*Monorail*	6; 22	2

H number	Name	Paper number	Total
H 14	Monorail hoist	2	1
H 15	Overhead monorail	8	1
H 16	Overhead power and free monorails system	8	1
H 17	Overhead traveling crane	4	1
H 18	Rail system crane	21	1
H 19	Stacker crane	2; 4; 5; 6; 7; 16; 22	6
H 20	Tower crane	16	1

Table 7: Industrial truck (IT)

IT number	Name	Paper number	Total
IT 1	Balance non-tilt truck	17	1
IT 2	Burden car	17	1
IT 3	Counter-balanced lift truck	4; 5; 6; 19; 20; 22; 25	7
IT 4	Counter-balanced order picker truck	17	1
IT 5	Counter-balanced rough terrain truck	17	1
IT 6	*Crane*	2	1
IT 7	Dollies	17	1
IT 8	Drive-elevating order picker	4	1
IT 9	Drum lifter	16	1
IT 10	Drum truck	16	1
IT 11	Fixed-platform truck	4	1
IT 12	*Forklift truck*	16; 29	2
IT 13	Four-wheel hand truck	2; 22	2
IT 14	Front-reach counterbalanced truck	17	1
IT 15	Front-reach outriggers truck	17	1
IT 16	*Hand lift truck/hand pallet truck*	2; 4; 16; 17; 20	5
IT 17	Hand platform with mechanical lift	17	1
IT 18	Hand platform with power lift	17	1
IT 19	*Hand truck*	4; 5; 6; 7; 19; 20	6
IT 20	Handcart	16	1
IT 21	High lift rider truck	2	1
IT 22	High lift walkie truck	2	1
IT 23	High-lift order picker	4	1
IT 24	*Lift truck*	7	1
IT 25	Low-lift order picker	4	1
IT 26	Material lift	16	1
IT 27	Narrow-aisle order picker truck	6; 22	2
IT 28	Narrow-aisle reach truck	4	1
IT 29	Narrow-aisle S/R truck	22	1
IT 30	Narrow-aisle side-loading lift truck	4; 22	2
IT 31	Narrow-aisle straddle-reach truck	22	1
IT 32	Narrow-aisle truck	16; 19	2
IT 33	Narrow-aisle turret truck	6; 22	2
IT 34	Outrigger aisle-guided orderpicker truck	17	1
IT 35	Pallet base stacker	4	1
IT 36	*Pallet jack*	1; 5; 6; 7; 22	5

IT number	Name	Paper number	Total
IT 37	Pallet set down truck	1	1
IT 38	*Pallet truck*	5; 6; 19; 22	4
IT 39	Pedestrian pallet truck	4	1
IT 40	Personnel and burden carrier	6	1
IT 41	*Platform truck*	6; 7; 19; 22	4
IT 42	Power-driven handtruck	16	1
IT 43	Power-driven platform truck	16	1
IT 44	Powered pallet truck	4	1
IT 45	Reach truck	25	1
IT 46	Rider pallet truck	20	1
IT 47	Rider stacker truck	20	1
IT 48	Shuttle truck	25	1
IT 49	Side-loader fork truck	4; 19; 20	3
IT 50	Side-loading outrigger truck	17	1
IT 51	Side-reach truck	25	1
IT 52	*Skid truck*	5	1
IT 53	Stand-on pallet truck/Stand-up pallet truck	1; 20	2
IT 54	Stand-on stacker truck	20	1
IT 55	Straddle base stacker	4	1
IT 56	Straddle carrier	2; 4; 22	3
IT 57	Tier platform truck	16	1
IT 58	Tow tractor with loading attachments	17	1
IT 59	Towing/Tow tractor	7; 17; 29	3
IT 60	Tractor trailer	2; 4; 5; 6; 19; 22	6
IT 61	Tractor-trailer train	16	1
IT 62	Turret truck	25	1
IT 63	Turret type outriggers truck	17	1
IT 64	Walkie lift	19	1
IT 65	Walkie pallet truck	20	2
IT 66	Walkie pallet truck with power lift	17	1
IT 67	Walkie stacker	2; 6; 20; 22	4
IT 68	Walkie truck	7	1

Table 8: Automated guided vehicle system (AGVS)

AGVS number	Name	Paper number	Total
AGVS 1	**AGVs**	17	1
AGVS 2	AS/R machine	22	1
AGVS 3	Automatically positioned stock selectors AGV	6	1
AGVS 4	Conveyor deck AGV	20	1
AGVS 5	Electric wire guidance	5	1
AGVS 6	Fork AGV	7; 19; 20; 22	4
AGVS 7	High-lift AGV	4; 16	2
AGVS 8	Laser Beam Guidance	5	1
AGVS 9	Lift deck AGV	4; 16	2
AGVS 10	Light-load AGV/Light-Duty AGV	6; 7; 19	3
AGVS 11	Low-lift AGV	4; 16	2
AGVS 12	Magnetic paint guidance	5	1
AGVS 13	Man-on-board AS/R machine	22	1

AGVS number	Name	Paper number	Total
AGVS 14	Manual load/unload AGV	4; 16; 20	3
AGVS 15	Pallet-load AGV	6	1
AGVS 16	Roller carrier	4	1
AGVS 17	Roller deck AGV	4; 16	2
AGVS 18	Side reach AGV	20	1
AGVS 19	Stationary deck AGV	4; 16	2
AGVS 20	Tractor AGV	6; 7	2
AGVS 21	Tractor train AGV	19	1
AGVS 22	Tugged AGV	4; 16; 22	3
AGVS 23	Unit-load AGV	6; 7; 19; 22	4

Table 9: Robot (R)

R number	Name	Paper number	Total
R 1	Electric robot	4; 16; 22	3
R 2	Hydraulic robot	4; 16; 22	3
R 3	Mechanical arm	22	1
R 4	Mechanised manipulator	4; 16	2
R 5	Pneumatic robot	4; 16; 22	3

Table 10: Pipe line (PL)

PL number	Name	Paper number	Total
PL 1	**Pipe line**	22	1

Legend:

Bold: MHE category.

Italic: MHE *class*.

CATEGORY number: synonym.

3. Warehousing equipment

3.1. Warehousing equipment analysis

The WE considered in papers are racks (RA), bulk warehousing systems (BWS), automated storage/removal systems (AS/RS) and other warehousing systems (OWS). They are described in Table 11.

Table 11: Warehousing equipment groups

Name	Description	Source
Racks (RA)	'A structure composed of two or more upright frames, beams, and connectors, for the purpose of supporting palletised materials in storage. Among the common methods of assembly are welded, bolted, or clipped.'	Institute of Industrial Engineers (2000)
Automated storage and retrieval system (AS/RS)	'A combination of equipment and controls which handles, stores, and retrieves materials with precision, accuracy and speed under a defined degree of automation. Systems vary from relatively simple, manually controlled order-picking machines operating in small storage structures to giant computer-controlled storage/retrieval systems totally integrated into the manufacturing and distribution process. Vertical heights of these latter systems can exceed 100 feet'.	Institute of Industrial Engineers (2000)
Bulk warehousing systems (BWS)	Open or sheltered warehousing systems of bulk products as liquids or dry products.	Tompkins and Smit (1988)
Other warehousing systems (OWS)	Warehousing systems other than the three mentioned groups (Mixed warehousing, Carousels, Modular, etc.)	Authors

3.2. Warehousing equipment statistics

The following tables (Table 12 to Table 15) present the details about considered WE in the papers and how many times each one is cited in the research. The first columns of the tables contain acronyms with a number referencing each WE type. The second columns contain the name of the WE types. The third columns contain the numbers of the papers citing the WE type. The fourth columns present the citation frequencies of each WE type.

Table 12: Racks (RA)

RA number	Name	Paper number	Total
RA 1	Deep lane	25	1
RA 2	Drive-in rack	6	1
RA 3	Drive-through rack	6	1
RA 4	Flow-through rack system	4; 22	2
RA 5	Package flow-through rack	6	1
RA 6	Pallet flow-through rack	6	1
RA 7	Pallet rack system	4; 5; 6; 16; 22; 25	6

Table 13: Bulk warehousing system (BWS)

BWS number	Name	Paper number	Total
BWS 1	Bulk storage system	4	1
BWS 2	Normal-block bulk storage system	22	1
BWS 3	Tight-block bulk storage system	22	1

Table 14: AS/RS

AS/RS number	Name	Paper number	Total
AS/RS 1	Deep-lane AS/RS	6	1
AS/RS 2	Man-on board AS/RS	4; 6; 22	3
AS/RS 3	Miniload AS/RS	4; 5; 6; 16; 22	5
AS/RS 4	Unit load AS/RS	4; 5; 6; 16; 22	5

Table 15: Other warehousing system (OWS)

OWS number	Name	Paper number	Total
OWS 1	Bin rack system	4; 22	2
OWS 2	Block stacking (stocking) in rack	4; 16	2
OWS 3	Block stacking (stocking) on floor	4; 16; 25	3
OWS 4	Cantilever rack system	4; 5; 6; 22	4
OWS 5	Carousels	5; 6	2
OWS 6	Mini rack	5	1
OWS 7	Mobile rack	5; 6	2
OWS 8	Modular drawer units	6	1
OWS 9	Portable rack	6	1
OWS 10	Shelving	4; 6; 16	3

4. Attributes

4.1. Attributes analysis process

The technical report Ahmed Bouh and Riopel (2015) introduced the attributes used in the papers about MHE selection. The new classification used in this research uses four attribute groups: unit load (UL), move (M), equipment (E) and area (A). They contend respectively variables permitting to determine the characteristics of the unit load, the required material handling movement, the inherent characteristics of the required equipment and the work environment.

Table 15 describes the process of transformation in order to move from different classifications used in each paper to a common classification of four groups. Some papers have not classified attributes and others have only one attribute group.

The first column contains the numbers of the papers. The second column contains the name of the groups and the quantity of attributes of each group. The third column divided in four sub-column presents the attributes under the new classification. The fourth column contains remarks describing the changes.

Table 16: Before and after the attributes classification

Paper number	Before	After				Remarks
		UL	M	E	A	
1	Material (4); Move (5); Method (6)	4	5	6		No changes (15 to 15)
2	Material (6); Move (13); Equipment (4)	6	14	2	1	No major changes (23 to 23)
3	Material (3); Move (4); Methods (4)	6	12	4	1	Changes (11 to 23) The additional attributes are attributes that are specified clearly but declared under other attributes. For example, three attributes are declared as Move characteristics attribute.
4	Material (13); Move (9); Operation (10); Area (4)	6	13	5	2	Changes (36 to 26). The number of attributes is reduced because all the duplicates are only considered once.
5	General (8), Material (8); Move (15); Operation and data treatment attribution (7)	11	16	16	1	Changes (38 to 44). The additional attributes are from six attributes that are regrouped in the paper as evaluation factors in General group and the Budget attribute divided in two.
6	Material (4); Move (7); Facilities (2); Equipment (2)	5	11			Changes (15 to 16). The additional attribute is Storage property which is used when selecting a WE.
7	Direct (8); Inferred (2); Direct/Inferred (2)	6	4	1		Changes (12 to 11). The attribute type of unit load is repeated. The appellations Compared to pallet and Palletised are used in the paper.
8	Unit load conveyor attributes and bulk load conveyor attributes.	5	7	6		Changes (20 to 18). Two attributes are repeated (Temperature and Distance called Horizontal carry).
9	Equipment (20)			6		No changes (6 to 6).
10	Equipment (20)			20		No changes (20 to 20).
11	Equipment (3)			3		No changes (3 to 3).
12						No attributes.
13						No attributes.

Paper number	Before	After				Remarks
		UL	M	E	A	
14	No classified. Unit load conveyor attributes.	2		4		No changes (6 to 6).
15	No classified.	4	2			No changes (6 to 6).
16	Material (6); Operation (6); Move (6); Area constraints (4).	6	10	3	2	Changes (22 to 21). The attribute Inventory turnover method used to select WE is ignored.
17	Material (2); Move (7); Method (11).	2	9	9	6	Changes (20 to 26). Attributes are mentioned in group.
18	Equipment (6)			6		No changes (6 to 6).
19	No classified. 28 attributes.	6	19	2	1	No changes (28 to 28).
20	Materials (6); Move (6); Operation (3); Area (6).	6	11	2	2	No changes (21 to 21).
21	Acquisition cost and operation cost. Equipment (2).			2		No changes (2 to 2).
22	Move (9); Material (9); Operation (7); Area (5).	7	12	7	3	Changes (30 to 29). The attribute Path is repeated (Move path and Motion path).
23	Unclear (21 specifications for overhead electrified monorail).					No changes. Unclear.
24	Missing information.					Missing information. A mathematical formula is presented.
25	Operation cost. E (1).			1		No changes (1 to 1)
26	23 criteria to select an equipment model.					No changes.
27	Acquisition cost and operation cost. E (2).			2		No changes (2 to 2).
28	No classified. 5 attributes.	1	1	4		Changes (5 to 6). The attribute Budget is ignored because Costs attributes are considered both. The attribute called Demand designate according to the given explanation the Quantity to handle and the Move distance attributes.
29	Minimising Acquisition cost and Operation cost.					No changes. Minimising costs.
30	Product (5); Process (6).	5	5	1		No changes (11 to 11).

4.2. Attributes statistics

In order to present a picture of the attributes and their frequencies, several aspects have been analysed. It became possible to harmonise the data presented in the papers.

- Our school of thought considers the MHE not being WE or auxiliary equipment. Consequently, all the attributes permitting to ask if the user wills to select either a WE, a positioning equipment, or a MHE, etc. are neglected when it is about selecting only a MHE.
    - Cho and Egbelu (2005) use an attribute called Type of equipment (movement, storage, positioning). The terms in parentheses are the values of the attribute. In other words, the user specify one of three terms.
    - Chu et al. (1995) have different attribute databases according to the equipment (Automated Storage/Retrieval System AS/RS, positioning equipment, etc.).

- When an attribute is repeated in a paper, only one generic attribute is counted. With all the duplicates, Chan et al. (2001) is displaying 36 attributes but there are only 26 attributes according to our analysis. For instance, Chan et al. (2001) are considering two or three times the same attribute.
    - Material type for storage/retrieval, material type for truck, and material type for AGV. These three attributes are simply called in this literature view material type.
    - Material weight for move category, material weight for crane, and material weight for robot. They are replaced by material weight.

- Each attribute should have values. Some attributes of some papers are not clear because their names and the values are different and not concordant with the majority of papers. When classifying according the four groups of this literature review, the name of the attribute is changed and takes the same name used by the others.
    - The attribute called Move type in Cho and Egbelu (2005) is not clear. According to its values (horizontal, inclined, rotational), it is classified as a Move direction attribute.
    - The attribute called Course in Park (1996) and Mirhosseyni and Webb (2009) is the attribute called Path by the other majority papers.
    - Fisher et al. (1988) use an attribute called Fragile (yes or no). This attribute is called Nature for all the other papers and considered so in this analysis. They also use an attribute called Moves/hour which is called in this literature review in papers Handled load/time unit.

- There is one case when an attribute is only used by two papers and becomes not clear because it takes totally different values in each paper. It is the attribute called Product mix. It is necessary to specify the type of the considered unit load in a material handling selection problem. For a palletised unit load, the problem of product mixity is not significant in material handling operation. No changes are made in this analysis and the attribute is specified for the two papers with the values high, medium and low representing the level of mixity of products.
    - According to Kim and Eom (1997), the values are flexible, normal and rigid. It is explained by the level of production flexibility required by the products.
    - According to Cho and Egbelu (2005) the values are high, medium and low. There is not other precision.

- Sometimes, the same attribute with the same values is called differently in papers. A common name is used in order to harmonise in this literature review. It is the case of the attribute Acquisition cost considered in twelve papers and the attribute Operation cost considered in nine papers. For instance:
    - Ahmed and Lam (2014) use the appellations Fixed cost for Acquisition cost and Variable cost for Operation cost.
    - Hadi-Vencheh and Mohamadghasemi (2015) use the appellations Purchasing cost for Acquisition cost and Setting up and operational cost for Operation cost. They also consider other costs such as Spare parts cost and Maintenance cost which are declared as other attributes.

- Some attributes are harmonised and renamed for more clarity.
    - The attribute Storage of Kim and Eom (1997) and the attribute called Interface of Fisher et al. (1988) are designating to ask the same question: does the material move involve transporting the material directly to and from a storage system for the electronics assembly? Yes or no. The common name From / To storage zone is used for both papers.
    - The attribute called Interface is used by Matson et al. (1992) and Chu et al. (1995) to determine the type of equipment interfaces, whether with racks, pick-up and delivery stations, AS/RS, conveyor… etc.
    - Fonseca et al. (2004) use the appellation Horizontal carry to designate the attribute Distance and Vertical Height to designate the attribute Lifting height.

- The attribute Aisle width classified as a Move attribute takes its values in metre or feet. It is used in eight papers. The similar attribute called simply Aisle and classified as an Area attribute is used to specify if aisles are applicable or not in the working area. It is only considered by Chakraborty and Banik (2006).

- Some additional attributes are used when selecting a WE.
    - The attribute Inventory turnover method (FIFO, LIFO) is used to select a WE. It is considered in the papers (Chan et al., 2001; Chu et al., 1995; Kulak, 2005).
    - The attributes Density (low, medium, high) and Access approach (man-to-part, part-to-man) are considered by(Chu et al., 1995).

- Sometimes, the values are not specified. It is the case of the attribute Origin / destination of Bookbinder and Gervais (1992). The attribute is mentionned as it is.

- Some papers don’t specify whether it is an acquisition cost or an operation cost. Malmborg et al. (1989) use the general attribute Cost and Cho and Egbelu (2005) the attribute Budget. They are classified in this analysis as Acquisition cost and Operation cost both.

The following tables (Table 16 to Table 20) present the result of the analysing work of each attribute and it frequency in the papers. The first columns contain acronyms referencing each attribute. The second columns contain the name of the attributes. The third columns contain the numbers of the papers citing the attribute. The fourth columns present the citation frequencies of each attribute.

Table 17: Unit load attributes (UL)

UL number	Name	Paper number	Total
UL 1	Annual demand	16	1
UL 2	Bottom surface	4; 5; 16; 19; 20; 22	6
UL 3	Complexity	15	1
UL 4	Corrosiveness	8	1
UL 5	Expected production trend	5	1
UL 6	Friability	8	1
UL 7	Height	5; 7	2
UL 8	Item range	4	1
UL 9	Length	5	1
UL 10	Material throughput	19	1
UL 11	Nature	2; 3; 4; 7; 16; 19; 20; 22; 30	9
UL 12	Number of material flow links	5	1
UL 13	Product mix	5; 15	2
UL 14	Quantity to handle	3; 5; 6; 22; 28	5
UL 15	Shape	1; 2; 3; 8; 20	5
UL 16	Size	2; 3; 4; 7; 8; 16; 19; 20; 22; 30	10
UL 17	Storage property	6	1
UL 18	Temperature	8; 22	2
UL 19	Type	1; 2; 3; 4; 5; 6; 7; 15; 16; 17; 19; 20; 22; 30	14
UL 20	Volume	1; 2; 3; 5; 6; 7; 15; 30	8
UL 21	Weight	1; 2; 4; 5; 6; 7; 14; 16; 17; 19; 20; 22; 30	13
UL 22	Width	5; 14	2

Table 18: Move attributes (M)

M number	Name	Paper number	Total
M 1	Aisle length	5; 16	2
M 2	Aisle width	2; 3; 4; 5; 6; 17; 19; 20	7
M 3	Angle of inclination	6; 8; 19	3
M 4	Automation	4; 16; 19; 20; 22	5
M 5	Automation level	5	1
M 6	Bidirectional flow	19	1
M 7	Control	3	1
M 8	Course	2; 3	2
M 9	Coverage area	2; 3; 4; 6; 16; 19; 22	7
M 10	Cross traffic	19; 20	2
M 11	Discharge	8	1
M 12	From/To storage zone	7; 15	2
M 13	Handled load	22	1
M 14	Handled load/time unit	2; 3; 7; 17; 19	5
M 15	Interface	6; 19	2
M 16	Level	2; 3; 4; 6; 16; 17; 22	7
M 17	Lifting height/Move height	4; 8; 16; 17; 22	5
M 18	Loading/unloading	8; 17; 19; 22; 30	5
M 19	Location	2; 3; 6; 17	4

M number	Name	Paper number	Total
M 20	MHE type transporting into storage	5	1
M 21	MHE type transporting out of storage	5	1
M 22	Move course	19	1
M 23	Move direction/plane	2; 4; 5; 8; 16; 19; 20; 22	8
M 24	Move distance	1; 2; 3; 4; 5; 6; 7; 8; 16; 17; 19; 20; 22; 28; 30	15
M 25	Move flow	19	1
M 26	Move frequency	1; 2; 3; 4; 6; 16; 17; 19; 20; 30	10
M 27	Move level	4	1
M 28	Move loop	22	1
M 29	Move pattern	5	1
M 30	Move route	19; 30	2
M 31	Move type	3; 4; 5; 16; 17; 19; 22	7
M 32	Nature of loading	19	1
M 33	Obstacle	2; 20	2
M 34	Operation accuracy	5; 15; 19	3
M 35	Operator reach height	4	1
M 36	Origin/destination	2	1
M 37	Origin/destination level	20	1
M 38	Path	1; 2; 3; 19; 20; 22	6
M 39	Path variability	2; 4; 5; 6; 7; 16; 20; 22	8
M 40	Speed	1; 3; 5; 6; 8; 30	6
M 41	Transaction data treatment	5	1
M 42	Truss height/Available height	1; 2; 3; 4; 5; 6; 16; 19; 20; 22	10
M 43	Type of MHE to be connected	5	1
M 44	Workstation types	5	1

Table 19: Equipment attributes (E)

E number	Name	Paper number	Total
E 1	Accumulation	7; 8; 19; 20; 30	5
E 2	Accuracy	10; 18; 22	3
E 3	Acquisition cost	1; 3; 5; 9; 10; 11; 14; 17; 18; 21; 27; 28	12
E 4	Adaptability	5	1
E 5	Angle of repose	8	1
E 6	Applicability	5	1
E 7	Attainability of experts for education, etc.	10	1
E 8	Attainability of spare parts	10	1
E 9	Controllability	1; 18	2
E 10	Convenience	10	1
E 11	Deck design	4	1
E 12	Economic	5	1
E 13	Engine type	17	1
E 14	Equipment Compatibility with others	28	1
E 15	Equipment profile complexity	8	1
E 16	Equipment range	18	1

E number	Name	Paper number	Total
E 17	Flexibility	8; 9; 10; 14; 18	5
E 18	Floor load capacity	2	1
E 19	Function	16; 22	2
E 20	Gripping equipment	17	1
E 21	Guarantee and after service	10	1
E 22	Host computer level	5	1
E 23	Integratability	5	1
E 24	Lead time	9	1
E 25	Lifting/loading/unloading speed	4; 5; 10	3
E 26	Loading capacity	8; 10; 17; 22; 28	5
E 27	Loading/Unloading automation level	5; 19	2
E 28	Loading/Unloading type	4; 22	2
E 29	Maintenance	1; 5; 10	3
E 30	Maintenance cost	10	1
E 31	Mean time to repair	9	1
E 32	Move automation level	5; 22	2
E 33	Move speed	10; 14	2
E 34	Operation control	3; 16; 20; 22	4
E 35	Operation cost	1; 3; 5; 10; 11; 14; 17; 21; 27; 28	10
E 36	Operation time per day	5	1
E 37	Operation type	5	1
E 38	Power source	3; 8	2
E 39	Primary function	2; 4; 5; 16; 22	5
E 40	Product protection	9	1
E 41	Ramps	17	1
E 42	Relationship with manufacture	10	1
E 43	Reliability	18	1
E 44	Repeatability	10	1
E 45	Rider/Walkie	17	1
E 46	Risk	10	1
E 47	Safety	1; 5; 10	3
E 48	Salvage value	10	1
E 49	Spare parts cost	10	1
E 50	Tires type	17	1
E 51	Transportation method	4; 16	2
E 52	Up-time	9	1
E 53	Utilisation level	11; 17	2
E 54	Variability	1	1
E 55	Volume and diversity of fuel	10	1
E 56	Weight control needed	5	1

Table 20: Area attributes (A)

A number	Name	Paper number	Total
A 1	Aisle	3	1
A 2	Exhaust	17	1
A 3	Floor space	4; 16; 22	3

A number	Name	Paper number	Total
A 4	Floor space nature	5; 17	2
A 5	Metal debris	17	1
A 6	Noise	17	1
A 7	Occupying aisle	20	1
A 8	Power availability	17	1
A 9	Rack deep	4; 16; 22	3
A 10	Slope	19	1
A 11	Space between column	2	1
A 12	Step	20	1
A 13	Storage area	22	1

Table 21: Warehousing attributes (W)

W number	Name	Paper number	Total
W 1	Access approach	6	1
W 2	Density	6	1
W 3	Inventory turnover method	4; 6; 16	3

5. Conclusion

The number and the quality of used data are important in the resolution of the MHE and WE selection problem. Researchers tend to use only the locally available equipment (Al-Meshaiei, 1999). Others restrict the resolution in a specific case. It could explain the statistics of not regularly distributed data in the literature. Our purpose is to treat the selection problem in a generic aspect in the upcoming works.

Another remark could be that there is a lack of French terminologies for some MHE particularly Bulk load conveyors. Fortunately, the dictionary Riopel and Croteau (2013) provides translations with definitions for almost all the other equipments.

6. References

Ahmed, A., & Lam, S. S. (2014). *Material Handling Equipment Selection Using Multi-Attribute Utility Theory and Monte Carlo Simulation.* Paper presented at the 2014 Industrial and Systems Engineering Research Conference, Toronto, Canada.

Ahmed Bouh, M., & Riopel, D. (2015). *Material handling equipment selection: New classifications of equipments and attributes* (CIRRELT-2015-63). Retrieved from https://www.cirrelt.ca/DocumentsTravail/CIRRELT-2015-63.pdf

Al-Meshaiei, E. A. E. S. (1999). *An expert system for material handling equipment selection.* (Ph.D.), University of Warwick, Warwick.

Bookbinder, J. H., & Gervais, D. (1992). Material-handling equipment selection via an expert system. *Journal of Business Logistics, 13*(1), 149-172.

Chakraborty, S., & Banik, D. (2006). Design of a material handling equipment selection model using analytic hierarchy process. *The International Journal of Advanced Manufacturing Technology, 28*(11-12), 1237-1245. doi:10.1007/s00170-004-2467-y

Chan, F. T. S., Ip, R. W. L., & Lau, H. (2001). Integration of expert system with analytic hierarchy process for the design of material handling equipment selection system. *Journal of Materials Processing Technology, 116*(2–3), 137-145. doi:10.1016/S0924-0136(01)01038-X

Cho, C., & Egbelu, P. J. (2005). Design of a web-based integrated material handling system for manufacturing applications. *International Journal of Production Research, 43*(2), 375-403. doi:10.1080/00207540420002688 66

Chu, H. K., Egbelu, P. J., & Wu, C.-T. (1995). ADVISOR: A computer-aided material handling equipment selection system. *International Journal of Production Research, 33*(12), 3311-3329. doi:10.1080/00207549508904876

Fisher, E. L., Farber, J. B., & Kay, M. G. (1988). MATHES: An expert system for material handling equipment selection. *Engineering Costs and Production Economics, 14*(4), 297-310. doi:10.1016/0167-188X(88)90034-1

Fonseca, D. J., Uppal, G., & Greene, T. J. (2004). A knowledge-based system for conveyor equipment selection. *Expert Systems with Applications, 26*(4), 615-623. doi:10.1016/j.eswa.2003.12.011

Gabbert, P., & Brown, D. E. (1989). Knowledge-based computer-aided design of materials handling systems. *IEEE Transactions on Systems, Man and Cybernetics, 19*(2), 188-196. doi:10.1109/21.31025

Hadi-Vencheh, A., & Mohamadghasemi, A. (2015). A new hybrid fuzzy multi-criteria decision making model for solving the material handling equipment selection problem. *International Journal of Computer Integrated Manufacturing, 28*(5), 534-550. doi:10.1080/0951192X.2014.880948

Hassan, M. M. D. (2010). A framework for selection of material handling equipment in manufacturing and logistics facilities. *Journal of Manufacturing Technology Management, 21*(2), 246-268. doi:10.1108/17410381011014396

Hassan, M. M. D. (2014). An evaluation of input and output of expert systems for selection of material handling equipment. *Journal of Manufacturing Technology Management, 25*(7), 1049-1067. doi:10.1108/JMTM-08-2012-0077

Hassan, M. M. D., Hogg, G. L., & Smith, D. R. (1985). A construction algorithm for the selection and assignment of materials handling equipment. *International Journal of Production Research, 23*(2), 381-392. doi:10.1080/00207548508904715

Institute of Industrial Engineers. (2000). *Industrial engineering terminology: a revision of ANSI Z94.0-1989 : an American national standard, approved 1998*: Industrial Engineering and Management Press.

Karande, P., & Chakraborty, S. (2013). Material handling equipment selection using weighted utility additive theory. *Journal of Industrial Engineering, 2013*, 9. doi:10.1155/2013/268708

Kim, K. S., & Eom, J. K. (1997). An expert system for selection of material handling and storage systems. *International Journal of Industrial Engineering, 4*(2), 81-89.

Kulak, O. (2005). A decision support system for fuzzy multi-attribute selection of material handling equipments. *Expert Systems with Applications, 29*(2), 310-319. doi:10.1016/j.eswa.2005.04.004

Malmborg, C. J., Krishnakumar, B., Simons, G. R., & Agee, M. H. (1989). EXIT: a PC-based expert system for industrial truck selection. *International Journal of Production Research, 27*(6), 927-941. doi:10.1080/00207548908942599

Maniya, K. D., & Bhatt, M. G. (2011). A multi-attribute selection of automated guided vehicle using the AHP/M-GRA technique. *International Journal of Production Research, 49*(20), 6107-6124. doi:10.1080/00207543.2010.518988

Matson, J. O., Mellichamph, J. M., & Swaminathan, S. R. (1992). EXCITE: Expert consultant for in-plant transportation equipment. *International Journal of Production Research, 30*(8), 1969-1983. doi:10.1080/00207549208948133

Mirhosseyni, S. H. L., & Webb, P. (2009). A hybrid fuzzy knowledge-based expert system and genetic algorithm for efficient selection and assignment of material handling equipment. *Expert Systems with Applications, 36*(9), 11875-11887. doi:10.1016/j.eswa.2009.04.014

Onut, S., Kara, S. S., & Mert, S. (2009). Selecting the suitable material handling equipment in the presence of vagueness. *International Journal of Advanced Manufacturing Technology, 44*(7-8), 818-828. doi:10.1007/s00170-008-1897-3

Park, Y.-B. (1996). ICMESE: Intelligent consultant system for material handling equipment selection and evaluation. *Journal of Manufacturing Systems, 15*(5), 325-333. doi:10.1016/0278-6125(96)84195-1

Public Works and Government Services Canada. (2015). Termium Plus, The Government of Canada's terminology and lingustic data bank. Retrieved from http://www.btb.termiumplus.gc.ca/tpv2alpha/alpha-eng.html?lang=eng&i=&index=alt&__index=alt&codom2nd=&srchtxt=FORWARD+CHAINING

Riopel, D., & Croteau, C. (2013). *Dictionnaire illustré des activités de l'entreprise : industrie, techniques et gestion* (Édition mise à jour ed.). Montréal: Presses internationales Polytechnique.

Sharp, G., Wan, Y.-T., McGinnis, L. F., Goetschalckx, M., Bodner, D., Govindaraj, T., . . . Everette, J. (2001). *A structured approach to material handling system selection and specification for manufacturing*. Paper presented at the Industrial Engineering Research Conference.

Telek, P. (2013). Equipment preselection for integrated design of materials handling systems. *Advanced Logistics Systems, 7*(2), 57-66.

Tompkins, J. A., White, J. A., Bozer, Y. A., & Tanchoco, J. M. A. (2010). *Facilities planning* (4 ed.). Hoboken: John Wiley & Sons.

Trevino, J., Hurley, B. J., Clincy, V., & Jang, S. C. (1991). Storage and industrial truck selection expert system (SITSES). *International Journal of Computer Integrated Manufacturing, 4*(3), 187-194. doi:10.1080/09511929108944494

Tuzkaya, G., Gülsün, B., Kahraman, C., & Özgen, D. (2010). An integrated fuzzy multi-criteria decision making methodology for material handling equipment selection problem and an application. *Expert Systems with Applications, 37*(4), 2853-2863. doi:10.1016/j.eswa.2009.09.004

Ustundag, A. (2014). Selection and Assignment of Material Handling Devices Under Uncertainty. In C. Kahraman & B. Öztayşi (Eds.), *Supply Chain Management Under Fuzziness* (Vol. 313, pp. 553-564): Springer Berlin Heidelberg.

Velury, J., & Kennedy, W. J. (1992). A systematic procedure for the selection of bulk material handling equipment. *International Journal of Production Economics, 27*(3), 233-240. doi:10.1016/0925-5273(92)90097-Q

Welgama, P. S., & Gibson, P. R. (1995). A hybrid knowledge based/optimization system for automated selection of materials handling system. *Computers & Industrial Engineering, 28*(2), 205-217. doi:10.1016/0360-8352(94)00200-7

Yaman, R. (2001). A knowledge-based approach for selection of material handling equipment and material handling system pre-design. *Turkish Journal of Engineering And Environmental Sciences, 25*(4), 267-278.