CONCEPT OF INTELLIGENT RECONFIGURABLE TROLLEYS FOR CITY MULTI-FLOOR MANUFACTURING AND LOGISTICS SYSTEM

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Abstract

The objective of this article is to present an innovative concept of intelligent reconfigurable trolleys for the city multi-floor manufacturing and accompanying transport operations that increase the efficiency and flexibility of production processes and supply logistics system. The characteristics of the original concept modular loading units in the form of intelligent reconfigurable trolleys are presented, with their construction and equipment description. Particular attention is paid to essential elements enabling real-time identification and monitoring of IRTs. Moreover, the supply management system based on intelligent reconfigurable trolleys is presented. The article ends with a description of the possibilities of further implementation and development of the technology under study.

Keywords: Multi-floor manufacturing, modular loading unit, intelligent reconfigurable trolley, flexible logistic system

1. INTRODUCTION

The trends of the urbanization are associated with providing of a green manufacturing and development of the concept of effective work in the urban environment [1,2,3]. This in turn is closely related to efficient logistics and mobility, improvement of the transport communication and creation of innovative technological equipment and products for the logistic system users [4,5]. Under these conditions, the city multi-floor manufacturing and city logistics with multi-floor warehouses in the residential areas of big cities are developed. The location of multi-floor manufacturing buildings directly in the residential area of a big urban agglomeration enforces the necessity of use “clean technologies” for products manufacturing. It is obvious that the enterprises of metallurgical and chemical industry, as well as heavy and medium-sized machinery are located in industrial areas away from inhabited areas. However, part "clean" components for such industries can be produced by city multi-floor manufacturing [2,6].

The purpose of the article is to present an innovative concept of intelligent reconfigurable trolleys facilitating shipment of freight for city multi-floor manufacturing and logistics. The first part will present trends in the development of loading units and their application in modern production and logistics processes. Next the description of modular loading units servicing in-hose production and accompanying distribution and production supply systems will be given. The following parts will present the concept of Intelligent Reconfigurable Trolleys (IRTs) including proposed variants of construction and equipment. Particular attention was paid to essential elements enabling real-time and monitoring of IRTs.

2. TRENDS IN DEVELOPMENT OF LOADING UNITS

The selection of the loading unit is closely dependent on the load that is carried and from the means of transport that transports it. There are obvious dependencies between the mass and form of the cargo and its packaging and the way it is transported. The key features of loading units are their size, durability and resistance to external conditions. At the same time, there is a need for the loading unit to be so versatile that it can be transported by various means of transport, even during one transport relation from the point of origin to the

point of destination. Hence, the requirement for unification and standardization of both cargo units as well as means of transport and transshipment devices. Standardization concerns technical parameters but also issues related to supply chain management. The purpose of established and widely disseminated standards is optimizing costs, reduction of transport time and improve of transport safety. The next-to-be loading unit has to be compatible with improved means of transport and newly designed transport chains [7,8]. For an efficient flow through these supply chains smaller logistic units (e.g. loose goods, small cargo, article units etc.) have to be bundled and transported with the use of mobile load units [9]. Some important requirements for the European market were identified in the TelliBox research project [10,11]. The desirable features of large loading units include: compatibility to trimodal transport (road, rail and sea); stackability, volume and loading capacity, theft proof and load safety, flexibility in handling technology (side handling, top lifting).

For small volume shipments especially for high-value goods the concept of smaller and more flexible cargo named micro-containers was implemented [12]. Such a standard micro-container should be able to store different types of goods and should fit into commercial delivery vehicles. The external dimensions of micro-containers have to be adapted to the internal dimensions of larger intermodal loading units. Hence, in this solution, the standardization of load units with their modularity as a feature of increasing the flexibility of the supply chain was combined.

Regardless of new trends in materials and construction technologies, loading units are systematically developed in the field of information technology applications. Ordinary loading units undergo the transformation process and become e-units or smart units. It is due to new value-added construction or equipment: electronic lock, Wi-Fi, RFID tag/unit, intelligent monitoring terminal, tracking device, etc. The manufacturers outdo each other in the proposed solutions whose common goal is to enable remote visibility and control of door-to-door supply chain. Based on modern IT tools the transport and logistics managers can monitor each cargo unit (micro-containers and large containers), perform predictive and/or prescriptive analysis and achieve the whole process integration, and synchronization [13].

3. MODULAR LOADING UNITS

The modular loading units are understood as universal logistics units which can be easily assembled from modular frames and are dedicated to flexible logistic processes [6,14]. The modular loading units are designed for storage and transportation of various freights, including bulk, liquid and solid-state [15,16]. The unification of the modular loading units is based on the use of two types of modular loading units that perform the value of the supporting structure (**Figure 1a**) and functional structure (**Figure 1b**) and produced in standard sizes: [14]. The choice of the material of the modular frames and the technology of their manufacture depends on the weight of the transported freight, the overall dimensions of the modular loading units (**Figure 2**). The module frame of the modular loading units can be manufactured from light metal alloys, for example, aluminum alloys, as well as from plastics or carbon plastics [15].

The modular loading units can be adapted to various means and transport technologies: cranes, conveyors, freight elevators, trucks, trams, trolleybuses, trains, air and water transport, etc. The modular loading units can be moved both inside and outside the warehouses pushed by hand or with the help of a pallet truck. The semi-electric power truck can service the modular loading units sequentially delivering them to a loading ramp or a storage area. The installation of an electric drive with accumulator batteries directly in the modular loading units is not effective because it results in additional and cost for each modular loading unit.

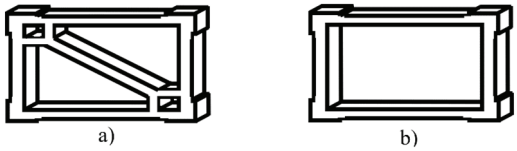

Figure 1 The construction of load-carrying modular frame (a) and functional modular frame (b) [14]

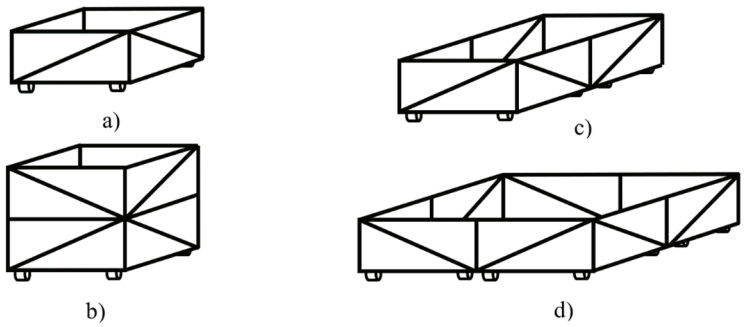

Figure 2 Schemes of the modular loading units assembled from modular frames [6]

One of the conditions of wide use of the modular loading units in the city multi-floor manufacturing and city logistics is the development of the concept of intelligent modular loading units, which would allow to identify and monitor their location, as well as their freights. Real-time information about the modular loading units and their freights is necessary for both transport operators and shippers. It contributes to the widespread implementation of the "Kanban Cards" philosophy in the multi-floor manufacturing, which reduces the storage time of freights and finished goods in warehouses and shortens the time of receipt of goods and services by customers [17].

4. CONCEPT OF INTELLIGENT RECONFIGURABLE TROLLEYS (IRTS)

The IRTs concept is a system of provisions defining the creation of an innovative transport designed to serve multi-floor manufacturing in the urban environment. The main provisions of the IRTs concept are as follows:

- increase the level of transport services for multi-floor manufacturing,
- simple and rapid transformation for the transport of new freights in flexible manufacturing conditions,
- transportation by various means of transport including: cranes, conveyors, semi-electric power trucks, freight elevators, pallet jack trucks, light and medium trucks, intermodal transport etc.,
- registration, certification, real-time identification and monitoring of IRTs,
- supply chain management in different levels of the manufacturing organization.

The implementation of these provisions is primarily related to the design specialization of the IRTs, the formulation of the principles of IRTs real-time identification and monitoring and supply chain management.

4.1. Construction types of the IRTs

The intelligent reconfigurable trolleys considering their adaptation to the user's needs can be in different structural configurations. Four basic construction types can be distinguished:

- general IRT - for storage and transportation of solid-state cargo without and with packaging,
- bulk IRT - for storage and transportation of bulk cargo,
- tank IRT - for storage and transportation of liquids,
- waste IRT - for storage and transportation of manufacturing and domestic waste.

Regardless of IRT type, they are all built from the basic components: load-carrying modular frames, functional modular frames and supporting frame with wheels. In addition to basic components there are operational and fleet ones. Operational components are closely related to the adaptation to the transported cargo and the desired functionalities and fleet components are necessary for connection, reloading and transport of IRTs in the dedicated transport system. The analysis of possible IRT design variants, considering their types and functional features is presented in the form of the morphological matrix (**Table 1**) [18].

Table 1 Morphological matrix of the IRTs' types

	IRT's components	Basic materials	Types of the IRT			
			general IRT	bulk IRT	tank IRT	waste IRT
Basic components						
A	load-carrying modular frame	a - light metal alloy; b -plastic	+	+	+	+
B	functional modular frame	a - light metal alloy; b -plastic	+	+	+	+
C	supporting frame with wheels	a - steel	+	+	+	+
Operational components						
D	boxes for bulk cargo	a - metal; b - plastic; c - fabric (tarpaulin)	-	+	-	+
E	tanks for liquids	a - metal; b - plastic (flexible); c - glass	-	-	+	-
F	shelves	a - metal; b - plastic	+	-	-	-
G	drawers	a - metal; b - plastic	+	-	-	-
H	cooling chambers	a - plastic and tarpaulin	+	-	+	-
Fleet components						
I	identification&monitoring device	a - type 1; b - type 2	+	+	+	+
J	fasteners for multi-IRTs	a steel	+	+	+	+

Each of the possible IRT design variants is assigned the IRT code. For example, general IRT for storage and transportation general cargo packages has the following IRT code: 1Aa4Ba1Ca4Ga1I1J. This IRT consists of one metal load-carrying modular unit, four metal functional modular unit, one frame with wheels, four metal drawers, one device for identification and monitoring and one set of fasteners for multi-IRTs connecting. The IRT code is stored in the database of IRTs fleet operator and is used in all data transitions generated by identification and monitoring device. The stored and transmitted data can be easily extended by information about IRT's owner, freight data, safety instruction, etc. This is the basis for IRT real-time identification and monitoring. There are several tracking systems available to use: GPS, NFC, GTIN, RFID, Barcode and all IOT compatible systems.

Selecting or changing the design of IRT is carried out by its owner, considering the market demand for this type of transportation services. The IRTs fleet operator can provide information to clients about the market needs for transport services [19, 20].

4.2. IRT-based supply chain management

The supply chain management "is to plan and coordinate all those activities necessary to achieve desired levels of delivered services and quality at lowest possibility cost" [21]. Fleet of IRTs can be the core element of the logistic system offering high-quality and cost-effective deliveries. The logistic operator managing the IRT fleet (IRTs fleet operator) should implement all actions to ensure the appropriate number and type of IRTs to meet the needs of all supply chain participants. It is important in the supply chain to avoid downtime of IRTs and timely delivery of goods with minimal costs. In this case, it is also necessary to consider the loss of time for the re-equipment, repair of the IRTs before their recycling.

Figure 3 shows the scheme of logistic supply chain with the use of IRTs. The presented system is applicable in large agglomeration areas in which production clusters include several of the multi-floor manufacturers. Each cluster has its own logistic node where IRTs are collected, stored, assembled and distributed. The IRTs fleet operator supplies the IRTs to producers in accordance with prior orders. Their transportation is carried out in light delivery trucks in the form of multi-IRTs. Multi-IRTs are easily assembled and disassembled at transshipment points within clients' manufacturing properties. Loading operations with the use of IRTs are made by the producers.

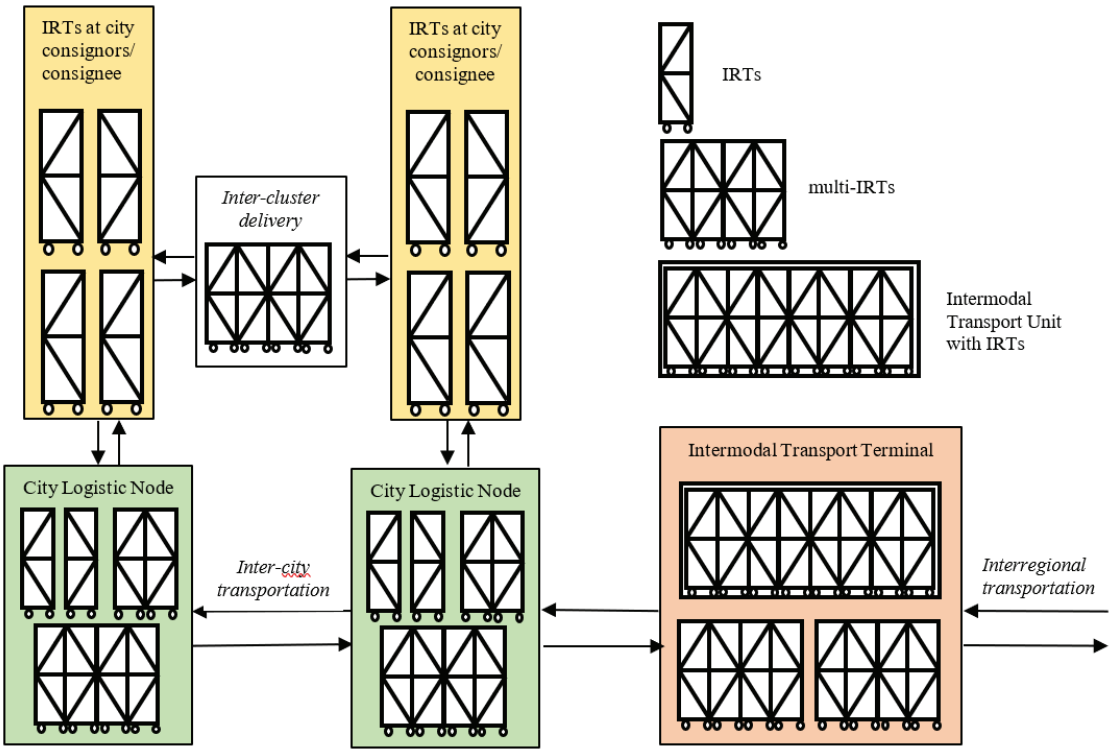

Figure 3 Logistic supply chain with the use of IRTs

IRTs with freight are delivered to the main stock at the ground floor of multi-floor manufacturing buildings [15] and there are sorted and formed into multi-IRTs. The main group is delivered to the nearest city logistics node and in justified cases IRTs or multi-IRTs are transported to other destinations within the same cluster. In city logistics nodes, IRTs are again sorted into two groups. In urban logistics nodes, IRTs are sorted into several groups. One group is delivered to Intermodal Transport Terminal, servicing interregional deliveries withy the use of rail or inland shipping transport. Remaining groups are delivered to other city logistic nodes within the same agglomeration.

5. CONCLUSION

The innovative concept of intelligent reconfigurable trolleys (IRTs) is intended to facilitate the city multi-floor manufacturing system. It is aimed to increase the efficiency and flexibility of production processes and accompanying transport operations. This logistic system can be successfully used in large urban agglomerations in which there are districts or separate production areas with the character of clusters. IRTs units are based on modular loading units' technology and their main advantage is adaptation for use in buildings and warehouses where there are narrow passages and freight elevators. Importantly, the IRTs design can be adapted to the transported cargo and required functionalities. It can also be easily modified during individual operating cycles. The process of assembling the IRTs is fast and can be carried out on any free areas in the warehousing or manufacturing locations.

The key IRTs equipment is a device for identification and monitoring that enable effective real-time management of the whole logistics process. Several core process areas can be distinguished: multi-floor manufacturing properties, city productions clusters, city logistic nodes, agglomeration transport network, intermodal transport terminal, interregional transport network. These crucial points and connections between them are covered the supply chain management system adapted to the needs of big cities that want to keep their production functions and at the same time meet the requirements of sustainable transport.

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REFERENCES

[1] FUJITA, M., Thisse, J. *Economics of Agglomeration: Cities, Industrial Location, and Globalization*, Cambridge University Press, 2013.

[2] WESTKÄMPER, E. *Towards the Re-Industrialization of Europe. A Concept for Manufacturing for 2030*, Springer, Berlin, 2014.

[3] SPATH D., Westkämper E., Hans-Jörgen B., Hans-Jürgen W. *Entwicklungen in der Unternehmensorganisation*, Berlin: Springer, 2017.

[4] DZHUGURYAN, T. *Design Features of Flexible Manufacturing Modules in Frame Construction*, Zeszyty Naukowe Politechniki Rzeszowskiej. Mechanika, Oficyna Wydawnicza Politechniki Rzeszowskiej, 84[284], nr 1/2012, 21-25.

[5] DZHUGURYAN, T., Jóźwiak, Z. *Infrastructure for Multi-Floor Virtual Enterprises System*, Systemy wspomagania w inżynierii produkcji, P.A. Nowa S.A. Gliwice, 3(15), 2016, 70-78.

[6] DZHUGURYAN, T., Wiśnicki, B., Jóźwiak, Z. *Modular Loading Units for Facilitating Multi-Floor Manufacturing and City Logistics*, Zeszyty Naukowe Akademii Morskiej w Szczecinie, Wydawnictwo Naukowe Akademii Morskiej w Szczecinie, nr 54 (126), 2018, s.

[7] JESCHKE, S. *Global Trends in Transport Routes and Goods Transport: Influence on Future International Loading Units*, Discussion Paper, 16th ACEA SAG Meeting, 2011.

[8] WIŚNICKI, B., DYRDA, A. An*alysis of the intermodal transport efficiency in the Central and Eastern Europe, Naše More* - International Journal of Maritime Science&Technology, 63(2)/2016, p. 43-47.

[9] GUDEHUS, T., KOTZAB, H. *Comprehensive Logistics*. Springer. Berlin. 2009

[10] TelliBox Deliverable no. D2. Report requirement specification, 2008, Available from: www.TelliBox.eu.

[11] RZECZYCKI, A., WIŚNICKI, B. *Strength Analysis of Shipping Container Floor with Gooseneck Tunnel under Heavy Cargo Load*, Solid State Phenomena, Vol. 252, 2016, p. 81-90

[12] HACKENBERG, G., *Mikrocontainer in der Logistik*. Konzeptpräsentation. Aachen. 2009.

[13] DEMPSEY, M., *Making the move to IoT, presentation at Intermodal Europe 2017 Conference*, ORBCOMM, 2017

[14] WIŚNICKI, B., DZHUGURYAN, T. *Flexible Logistic Processes with the Use of Modular Loading Units*, Technologia i automatyzacja montażu, nr 2, 2018, 16-20.

[15] DZHUGURYAN, T., JÓŹWIAK, Z. Impr*oving the Logistics of the Multi-Floor Assembly Manufacturing,* Technologia i automatyzacja montażu, nr 2, 2016, 16-20.

[16] DZHUGURYAN, T., JÓŹWIAK, Z. *The Transport Providing of Works of the Multi-Floor Flexible Production Line*, Autobusy: technika, eksploatacja, systemy transportowe, nr 6, 2016, 1311-1314.

[17] SODKOMKHAM, T., CHUTIMA, P. *Lean Six Sigma Application in Rear Combination Automotive Lighting Process*. IOP Conference Series: Materials Science and Engineering, 131(1). 2016.

[18] ZWICKY, F. *Morphologische Forschung.* Winterthur AG, Winterthur, 1959, Neuaufl. Baeschlin, Glarus 1989, 131 p.

[19] WAYN, CH. J., LI, B., DEMPSTER, A., G., RIZOS Ch. *GPS/WiFi Real-Time Positioning Device: An Initial Outcome, In Location Based Services and TeleCartography II - From Sensor Fusion to Context Models, Lecture Notes in Geoinformation and Cartography,* Gartner G., Rehrl K., Springer Berlin, Heidelberg, Germany, 2009.

[20] DUDEK, T. *Selection method of a logistics company IT system. A highly efficient infrastructure to respond, change and to drive innovation.* Transportation Research Procedia. Vol 16, 2016.

[21] CHRISTOPHER, M. *Logistics & Supply Chain Management: creating value-adding networks*, Prentice Hall, 2010