

Monitoring and managing KPIs of Material Handling performance in operative logistics

Huyen Thanh Vuong

Bachelor's thesis

May 2020

School of technology

Degree Programme in Logistics Engineering

Author(s) Vuong, Thanh Huyen	Type of publication Bachelor's thesis	Date May 2020 Language of publication: English
	Number of pages: 58	Permission for web publication: X
Title of publication Monitoring and managing KPIs of Material Handling performance in operative logistics		
Degree programme Degree programme of Logistics Engineering		
Supervisor(s) Franssila, Tommi		
Assigned by		
Abstract <p>Measuring and evaluating performance of operative logistics activities, especially Material Handling operation, become more crucial nowadays in any business among automotive industry. A data dashboard named Qlik Sense, which is used for monitoring, directing and controlling performance of Material Handling department at Hirschmann Automotive was designed and implemented into the company's daily business managerial activities.</p> <p>In order to determine critical KPIs (Key Performance Indicators) which are utilized in the presented data dashboard, a research was completed based on both theoretical findings and real-life practical experiences of professionals whose duties are related to operational logistics activity and its performance. A significant number of possible measuring indicators were discovered, from which 8 (eight) indicators were decided as the most critical KPIs for operative logistics activity and chosen to be implemented into the data dashboard. Real-time information obtained from the data dashboard was used to evaluate, control and improve the current performance of Material Handling's activity-based performance.</p> <p>The presentation of determined KPIs in measuring system Qlik Sense applies purposefully for logistics managers to assess Material Handling performance in regular basis. Furthermore, data obtained from the designed measuring tool is benefited to serve variety of departments related to logistics application. Beside the current advantageous characteristics of determined KPIs, further potential development in the future is expected, in order to endure with the natural growth of logistics business world.</p>		
Keywords/tags (Material Handling performance; KPIs in Logistics management; Operational logistics activities; Warehousing management)		
Miscellaneous (Confidential information)		

Contents

1	Introduction	5
1.1	Objectives	5
1.2	Motivation and background circumstance	5
1.3	Hirschmann Automotive at a glance	6
1.3.1	Worldwide locations.....	6
1.3.2	Company products.....	8
1.4	Structure of Material Handling department at Hirschmann Automotive (headquarters in Vorarlberg, Austria)	9
1.4.1	Goods Receiving	10
1.4.2	Production Line Supply and Put-away.....	11
1.4.3	Pick and Pack	11
1.5	Thesis progress	12
2	Theoretical basis.....	13
2.1	Material Handling in operative logistics.....	13
2.2	Special Material Handling consideration	14
2.3	Material Handling efficiency influenced by different aspects in packaging 15	
2.3.1	Product characteristics	15
2.3.2	Unitization	16
2.3.3	Communication	16
2.4	Performance measurement in operational logistics.....	17
2.4.1	Objectives of performance measurement	17
2.4.2	General logistics internal performance measurement	17
2.5	Characteristics of an ideal measurement system	19
2.6	Ideal report structure	19

	2
2.6.1	19
2.6.2	20
3	20
3.1	20
3.2	21
3.3	22
3.4	23
3.5	26
3.5.1	27
3.5.2	29
4	31
4.1	31
4.2	32
4.2.1	32
4.2.2	35
4.2.3	42
5	50
5.1	50
5.2	51
5.3	53
References	54
Appendices	58

Figures

Figure 1. Locations of Hirschmann Automotive plants.....	7
Figure 2. Hirschmann Automotive turnover 2008-2018.....	7
Figure 3. Hirschmann Automotive popular products	8
Figure 4. Hirschmann Automotive products in applications.....	8
Figure 5. Fundamental Material Handling activities within a typical warehouse.....	10
Figure 6. Key Performance Indicator (KPI) Board (Minghini, 2015).....	22
Figure 7. General overview of Handling Unit measurement	33
Figure 8. Cartons ratio by each Hirschmann plant.....	34
Figure 9. Cartons ratio at Hirschmann Automotive Austria.....	34
Figure 10. General overview of Delivery measurement	35
Figure 11. Deliveries by ship to party.....	36
Figure 12. Delivered quantities to customer Daimler AG in 2019 (year-to-date)	38
Figure 13. Number of delivered items to customer Daimler AG in 2019 (year-to-date)	38
Figure 14. Delivered quantities to Hirschmann Nantong plant in 2019 (year-to-date)	40
Figure 15. Number of deliveries to Hirschmann Nantong plant in 2019 (year-to-date)	41
Figure 16. Number of delivered items to Hirschmann Nantong plant in 2019 (year-to- date)	42
Figure 17. Number of transfer orders and number of transfer order items	44
Figure 18. Storage type categorisation of number of transfer orders and number of transfer order items	46
Figure 19. Number of transfer orders in August 2019 sorted by warehouse type.....	47
Figure 20. Number of transfer orders in 2019 (from January to August) handled by all storage locations	48
Figure 21. Number of transfer orders for finished goods in 2019 (week 01 to week 35)	48
Figure 22. Number of transfer order items for finished goods in 2019 (week 01 to week 35)	49

Tables

Table 1. Number of Delivery Notes	27
Table 2. Number of item positions.....	28
Table 3. Percentage of inspection lot.....	28
Table 4. Number of suppliers	28
Table 5. Percentage of mixed pallet.....	28
Table 6. Number of single boxes	29
Table 7. Average storage duration	29
Table 8. Warehouse utilization	30
Table 9. Material movement rate	30
Table 10. Order picking performance	30
Table 11. Number of different materials in the warehouse	31

1 Introduction

1.1 Objectives

The thesis aims to define the essential operative logistics KPIs (Key Performance Indicators) of Material Handling department at Hirschmann Automotive – a reputable supplier in automotive industry for recognized car manufacturing companies, such as Daimler or BMW. Based on the results of selected KPIs, a data dashboard named Qlik Sense is created, which provides visual tracking, monitoring and controlling of Material Handling's activity-based operations. All the critical KPIs and their visualizations achieved from Qlik Sense will be implemented in weekly shop-floor meetings of Material Handling department at Hirschmann Automotive, which can be used as a profitable tool to gain real-time picture of the team's performance. Consequently, necessary adjustments and improvements will be immediately observed, as well as appropriate developing direction will be determined. The implementation of Qlik Sense data dashboard will be first applied for the Material Handling operations at headquarters of Hirschmann Automotive, located in Vorarlberg, Austria. Following by the initial successful application, it is expected to be occupied as well in other Hirschmann plants, which are positioned in China, Mexico, Czech Republic, Romania and Morocco.

On the other hand, as the developing and implementing phase of a brand-new dashboard application is a time-demanding progress, the project will not be completely accomplished within the course of this thesis. The continuous progress will be furtherly proceeded, as there are always plenty of rooms for improvement on every business perspective.

1.2 Motivation and background circumstance

Nowadays, in dynamic logistics world, daily operational activities in Material Handling department are considered with high sense of speed, dynamicity, complexity, and flexibility. Therefore, it is important to frequently track and monitor the essential KPIs, which aims for the efficiency and effectiveness of warehousing performance. The principle of logistics is always understood as delivering things from one location

to another at the right time, right place, with right quantity and quality. In order to achieve that goal, the administrative staffs, who initially decide the amount of certain products to be delivered to intended parties, and warehousing team need to build a good communicative and collaborative relationship. As an example, based on decisions made by Customer service team, warehousing members are going to physically pick and pack the requested goods and prepare the delivery. There are plenty of goods movements in daily operation at Hirschmann Automotive's warehouse, which requires all the actions must be performed correctly at the right time manner. From the administrative point of view, it is necessary and important to gain a proper view about Material Handling's activities and its KPIs, so that one should obtain a comprehensive understanding of all challenges and difficulties that the department is demanded to deal with in their daily operation.

1.3 Hirschmann Automotive at a glance

1.3.1 Worldwide locations

"If you already think today about tomorrow, you are never outdated". This is the slogan of approximately 5500 employees in seven (7) different plants of Hirschmann Automotive. Thanks to products such as electrical connection systems and sensorial measurement systems, Hirschmann owns a continuous progress in the range of automotive recorded. In this way Hirschmann Automotive has developed to become a qualified partner and global player in worldwide automotive market during 60 years company history.

The foundation in Rankweil (Austria) took place in 1959. With the ambition to become international, Hirschmann opened the plant in Vsetin (Czech Republic) in 2003 and the factory in Tirgu Mures was established in 2008, following by the expansion in 2012 with the establishment of another Hirschmann plant in Kenitra (Morocco). In 2013, Hirschmann want a step further to deeply enter the potential Asian market by the foundation of Hirschmann Automotive (Nantong) in China. However, the enlargement did not stop since then, as in the beginning of 2018, the acquisition procedure of Geissler Präzisionserzeugnisse GmbH (Germany) has been successfully completed, as a step into a prosperous, secured and shared future.

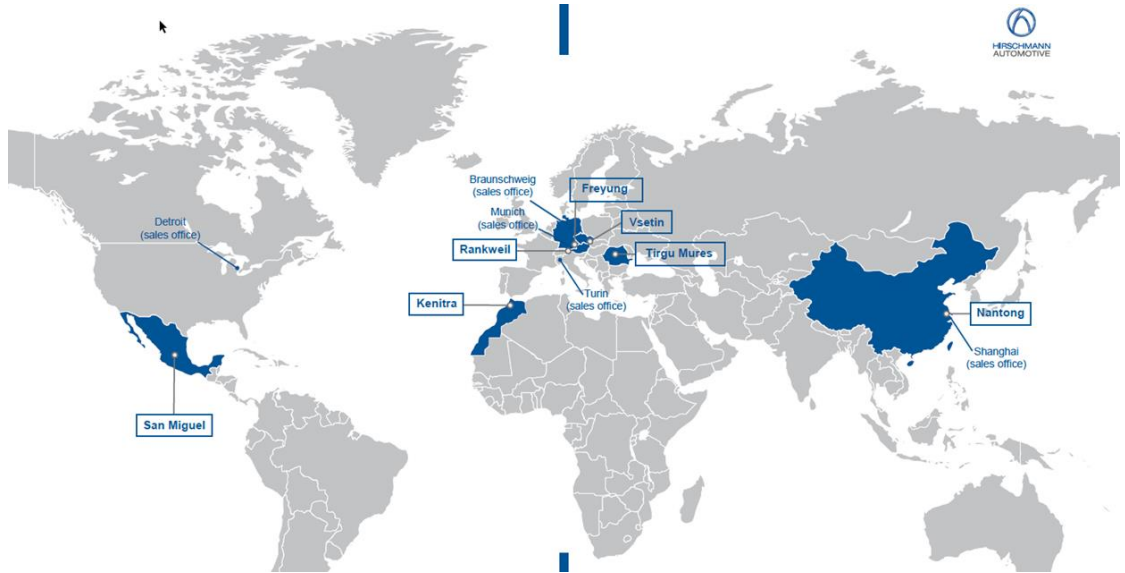


Figure 1. Locations of Hirschmann Automotive plants

Hirschmann Automotive has successfully performed a sustainable growth during the past ten years of the company’s global development. Becoming the competitive player in not only producing standard products, but also designing customized solutions for individual customers, Hirschmann was observed with stable increases on an average of 12% of annual turnover since 2010, reached 385 million Euro in 2018.



Figure 2. Hirschmann Automotive turnover 2008-2018

1.3.2 Company products

Hirschmann Automotive stands for movement and safety of the automobile road traffic and its participants. Currently the product line consists of four major product groups:

- Over moulding technology (for example: axial cabling system);
- Connector systems (for example: vibration-resistance special plug-in system);
- Special cable assemblies (for example: intelligent exterior cabling);
- Sensor systems (for example: position and expediting sensor technology);

Some popular products of Hirschmann Automotive as well as their applications can be seen below.



Figure 3. Hirschmann Automotive popular products

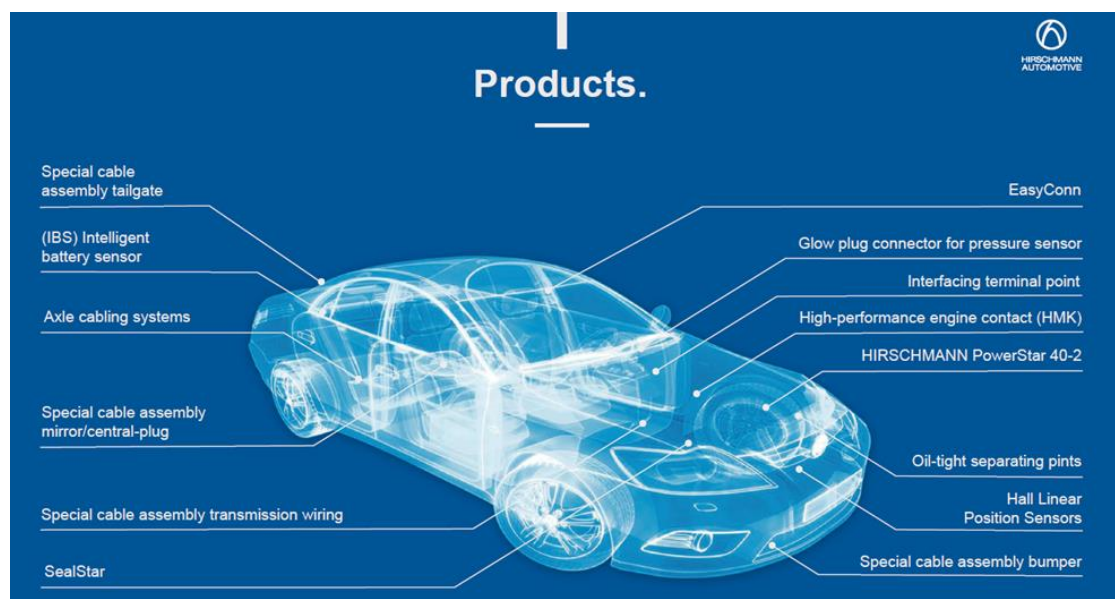


Figure 4. Hirschmann Automotive products in applications

A number of well-known automobile manufacturers as well as their first and second tier suppliers are currently valued customers of Hirschmann Automotive, on the level of daily enterprising partnership. Within the OEMs (Original Equipment Manufacturer), various automobile manufacturers are presented, such as Daimler, BMW or VW (Volkswagen) Group. In the field of CAMs (Computer-Aided Manufacturing), Hirschmann names Bosch, ZF and Thyssenkrupp as its valued customers. Furthermore, Hirschmann is supplier for some popular harness makers in the market, Dräxlmaier, Leoni or Yazaki for instance.

1.4 Structure of Material Handling department at Hirschmann Automotive (headquarters in Vorarlberg, Austria)

Theoretically, Material Handling operation is mainly performed within warehouse facility, which contains materials, parts, and finished goods on the move (Bowersox & Closs, 1996). While movement and storage are the fundamental aspects of any warehouse management's interest, in the course of this thesis research, only the measurement of goods movement's efficiency and effectiveness will be concentratedly studied. Optimal designation for warehouse structure will be beyond of scope for discussion.

It is aware of the fact that basic distinguished aspect in Material Handling occurs in handling of bulk materials and master carton materials. Bulk materials are usually referred to solids, fluids, or gaseous materials, without the necessary of carton packaging involved. On the other hand, 97% of the products portfolio at Hirschmann Automotive are treated as master carton materials. Certainly, as master carton materials share the majority of workload in handling activities, the concentration in controlling its operating performance is worth mainly invested in.

As being the headquarters of Hirschmann Automotive, the plant in Vorarlberg, Austria operates as of not only managing its individual running business, but also functioning as a hub for goods movements from the headquarters to other international plants. Therefore, the operation of Material Handling department is considered dynamic, sophisticated and flexibility-demanded. Material Handling team needs to han-

wide variety of goods movement, including managing incoming goods from both internal and external suppliers, processing put-away and storing, assuring materials supply and disposal for different production segments, ensuring availability of materials for crossed-company deliveries – which are shipments from the headquarters to other Hirschmann plants. With high sense of complexity, the transparency in measuring and controlling of the team's operative activities becomes more critical and demanded.

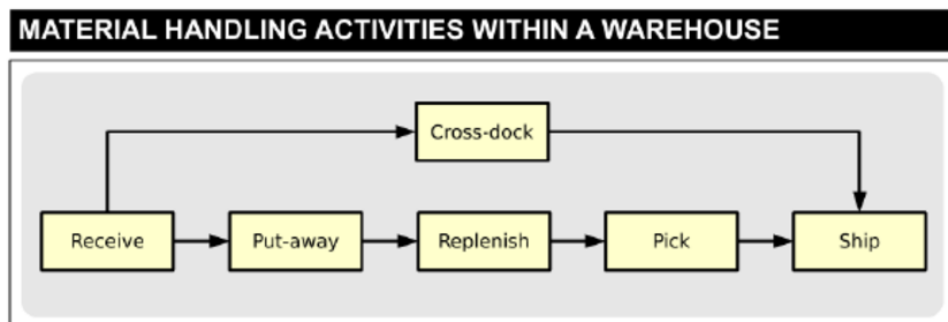


Figure 5. Fundamental Material Handling activities within a typical warehouse

Hirschmann Automotive's Material Handling division consists of three sub-divisions, which are Goods Receiving, Production Line Supply and Put-away, and Pick and Pack. Specific functions of each sub-division are described in the following parts.

1.4.1 Goods Receiving

Goods Receiving responsible staffs perform visual check concerning incoming shipments from either external suppliers or other Hirschmann plants, which are indicated as internal suppliers. In case of damages occurred to the incoming goods, team members proceed the progress according to the company regulation for handling damaged shipments. Incoming goods will be brought to Quality department for further quality check if necessary. Administrative booking presentation in SAP system for incoming goods is as well performed by the team. After that, Good Receiving team member coordinates the follow-up mobilization of received materials, whether proceeding put-away into appropriate warehouse locations, supplying for the productions, or cross-docking – which is understood as the materials will be sent directly to shipping area, then dispatched to external warehouse storage location or other Hirschmann plants.

Depending on specific incoterm applied on individual supplier, unloading activities can also be performed by Goods Receiving staff of Material Handling department.

1.4.2 Production Line Supply and Put-away

Production Line Supply is in charge for transferring and selecting raw materials and semi-finished products, which are supplied for different in-house production segmentations. The team assures the availability of those materials needed for production lines at their disposals. Besides, they are also responsible for raw materials put-away, handling all activities in the warehouse storage. Professional skills such as forklift truck driving is demanded for all the team members. Besides activity-based tasks, they perform additionally all needed systematic transactions in SAP for goods booking, withdrawing and putting on stocks.

As at Hirschmann Automotive, there are two different warehouse locations for raw materials, semi-finished goods and for finished goods, the Production Line Supply team is in control of raw materials and semi-finished goods warehouse. Therefore, not only supplying for the production lines, but the team handles also the selection and mobilization of raw materials from storage to packing station, which eventually will be delivered to other Hirschmann plants. For certain product portfolios, Hirschmann Automotive Austria plays the role as supplier of raw materials for other company' plants. Therefore, those materials will be produced at the headquarters, then delivered to other plants to continuously be utilized in the productions of finished products, which are purchased by end customers.

1.4.3 Pick and Pack

Pick and Pack team is required in close communication with Customer service officer and Crossed-company planner. Their tasks are concerned to preparing goods according to Delivery Note (DN) issued by mentioned administrative executives. Single shipments sent to individual customers, full-truck loads sent to Hirschmann European plants (in Czech Republic and Romania) and Morocco, as well as weekly containers sent to oversea plants (in China and Mexico) will be prepared to ready-to-ship by Pick and Pack team members. The daily workload required to be handled is enormous (further detailed figures can be seen in later chapters of the thesis).

All the delivery notes for shipments to individual customers which are assigned to dispatch daily need to be issued before 10 o'clock in the morning, so that Pick and Pack team should have sufficient time to prepare the goods, then transfer the fully packed goods to Transport and Customs team. As there are pre-defined number of trucks and containers to be shipped to other Hirschmann plants, occasionally the flexibility of transport fleets is lacked. Therefore, Pick and Pack team should obtain exact instruction and information from administrative executives – Crossed-company planner – to assure that prioritized urgent materials will be sent out on time. By the close communication and cooperation, the need of special transport such as taxi or airfreight will be eliminated.

It is known that the general fundamental principle of Logistics is to perform the mobilization of things to the right destination, at the right time, with right quantity and defined quality, not beyond desired optimal costs. Apparently, it can be seen that Pick and Pack team plays an essential role in accomplishing the mentioned obligations.

1.5 Thesis progress

The thesis will start with determination and classification of critical KPIs set for operative logistics performance at Hirschmann Automotive, specifically concerning activity-based progression in Material Handling department. The research is done both based on theoretical basis of general fundamental logistical management, and practical perspectives from associated employees at Hirschmann Automotive. The reason why the topic was chosen as well as the demanded objectives will be presented.

A list of possible potential KPIs for measuring Material Handling performance will be examined, in order to choose the most critical, benefitted and value-informative indicators for the implementation. Based on defined obligated KPIs, together with technical supports regarding IT (Information Technology) perspectives from IT department, a data dashboard named Qlik Sense is developed and implemented. Qlik Sense will be benefitted in daily operation of Material Handling division, as an excellent managerial tool to track, monitor, direct and control the team' performances. In reliance on real-time measurements obtained from Qlike Sense, further development

and improvement to enhance the efficiency and effectiveness of Material Handling operation will be constructed.

As a practical application of Qlik Sense in daily running business, its utilization for reporting purpose used in weekly shop-floor meetings of Material Handling team will be presented. The team should observe the actual broad picture of their own achievement in accomplishing particular tasks, number of boxes or pallets get fully packed and ready-to-ship in each working hour can be an example. From the managerial point of view, it is important and essential to gain both an overview and a detailed rate in their team's presentation.

Further discussion regarding outcome results of the project will be mentioned in chapter 4. As Qlik Sense is a brand-new tool to be designed and implemented in the company's business operation, expectedly, it might demand up to two years from the start until the tool will be fully accomplished. Due to that reason, within the course of this thesis work, only the procedure until upon current development will be considering presented. However, the thesis author will still continuously follow the improving phase of this project at Hirschmann Automotive, as it is mentioned earlier in the introduction, there is a close cooperation needed between Crossed-company planner – job position of the thesis's author – and Material Handling team.

Certainly, besides potential opportunities for the future development, there are particular limitations of the project which currently could not be fully covered, such as how new-defined KPIs will be implemented if there is the need, or how to design a customized set of essential KPIs for each plant of Hirschmann Automotive, as each location owns specific functional tasks corresponding its individual role in the supply chain.

2 Theoretical basis

2.1 Material Handling in operative logistics

According to Bowersox Donald J. and Closs David J. (1996, 418), professors of Business Administration and Logistics at Michigan State University, the handling of products is a key to warehouse productivity for several important reasons.

First, it was mentioned that the required number of labour hours to perform Material Handling operation would definitely has a negative impact on any reduction in the output rate per labour hour. Nowadays, even though there are certain benefits obtained thanks to improved and modern informatic technologies, it is still considered that Material Handling operation is highly activity-based presentation with intensive-labour need. Next, in reliance on recent business circumstances, from neutral point of view, Material Handling today should have received more critical supervision and attentiveness from the top management's interests of any business, especially in an extreme dynamic field such as automotive industry. Finally, although it cannot be denied that the recent development of automation technology that potentially could be applied in Material Handling is reaching beyond expectations, it is only at the starting phase of the implementation. (Bowersox & Closs, 1996). Hirschmann Automotive can be considered as an example in this case. The company has designed to build an automated warehouse that should be accomplished and ready to use in three years in the future. However, until the current business development phase, Material Handling cannot be operated without the majority demand of labour resources.

Activity-based operation in Material Handling therefore requires an immediately real-time measuring, monitoring, controlling and directing the tasks' accomplishment. Apparently, output results obtained by labour work cannot be as stable and controllable as ones performed by corresponding automated warehouse system. Moreover, the requisite labour resources in goods handling and operating represent one of logistics highest personnel cost components (Bowersox & Closs, 1996). Therefore, from both managerial and cost-effective point of view, it is critical and essential to design a concrete systematic tool which captures all the most operative and strategic indicators of Material Handling performances.

2.2 Special Material Handling consideration

As discussed, the primary objective of Material Handling activity is considered movements of materials from manufacturing location to point of sale. Nowadays, however, 'reverse logistics', which refers to managing returned goods, deserves more

and more attentive concentration from logistics administrative point of view. The elemental requirements are accelerating all the processing steps needed to provide customer credit, issuing exchanged orders, and making returned items available again for sale, if applicable (Levans, 2019). Due to variable reasons, a delivered item can be recalled to the manufacturer or shipper. They can be excessive deliveries, defected items, or incorrect shipping elements. In any applied circumstance, manual handling is demanded to effectively handle the reverse flow of goods. As in today world of logistics, Material Handling of two-way movement is crucial.

2.3 Material Handling efficiency influenced by different aspects in packaging

Packaging is recognized to play a centrally essential role in improving and enhancing logistical productivity and efficiency. Material Handling operations are affected by packaging designation and standardization, in multiple dimensions such as truck loading and unloading productivity, warehousing pick-and-pack performance, storage and transportation utilization.

Critical KPIs in Material Handling are apparently influenced by packaging aspect. While operational logistics productivity is measured fundamentally by the ratio of the output of a logistical activity (truck loading – unloading, goods pick-and-pack) to the input (required labour's working time), packaging is considered to increase the output (Bowersox & Closs, 1996). With a standardized packaging classification, number of carton boxes to be picked or loaded per hour will be improved, container or truck loading will be at the most optimal utilization, for instances.

2.3.1 Product characteristics

Each product type of Hirschmann Automotive is stored and packed in different packaging classifications, depending on product characteristics.

Automotive components like connectors, contacting applications, cable assemblies or sensors are usually packed in standardized carton boxes (non-returned packaging) or Small Load Carriers (SLC, often made from plastic materials, possible to be returned and reused). There are limited types of carton boxes, identified by the specific

dimensions, are used at Hirschmann Automotive, in order to optimize the storing and loading efficiency in the warehouse, as well as in transportation. Bulk materials, used for production of finished products, such as plastic granules are packed in durable plastic bags or pallet-sized octabins, which is considered the most optimal packaging method for this type of material.

2.3.2 Unitization

Despite the dissimilarity of product characteristics, standardization in packaging is considered one of the most crucial aspects that is obligated for the improvement of Material Handling performance.

Strong, firm and durable packaging enhances the efficiency and effectiveness of goods handling in the warehouse. Processes such as check-in, loading, unloading, put-away, or pick-and-pack are simplified and optimized as the result of standardized packaging. Besides, the risk of damages during movements can also be reduced. Consequently, optimal packaging is capable of decreasing the required input and increasing the obtained output in general Material Handling operations. Furthermore, standardization generally results in simplicity, transparency, and unification in monitoring and measuring performances.

2.3.3 Communication

Information flow should not be considered to a smaller extent comparing to physical materials flow in the warehouse's daily operation. Tracking system at Hirschmann Automotive allows responsible employees to access on complete packing information of a certain product, including standard packaging quantity (SPQ), dimensions of packing material, as well as how packing units should be stacked on a pallet. Additionally, the system also provides exact location of each particular product in the warehouse, which is essentially required for immediate and optimal access in materials handling. Above mentioned criteria are necessary for the most advantageous and referable measuring strategy of Material Handling performance.

2.4 Performance measurement in operational logistics

Nowadays, in the dynamic logistics world, quality information is required to be provided on-demand with a rapid response, in order to evaluate the present business situation within limited time manner. Therefore, there is a need to replace old reporting formats by modern computer-based controlling system.

2.4.1 Objectives of performance measurement

Monitoring function allows the management to track historical logistics performance, which can be reported to related parties. Long-term performance's evaluated figures can be used in order to determine the targeted ideal achievement. On the other hand, controlling function measures the ongoing performance of addressed department, which supports immediate detection when the result exceeds defined limits. Finally, directing function is designed on purpose of motivating and encouraging employees to accomplish the best possible performance. Based on defined target for each activity-based logistics operation, apparently, both effective and ineffective performance need to be measured, with the aim of potentially improving the current circumstances.

2.4.2 General logistics internal performance measurement

Theoretically, there are some fundamental aspects usually being measured in order to evaluate the performance of logistics operations, such as cost, customer service, productivity, and quality (Bowersox & Closs, 1996).

Cost is considered one of the most crucial and reflective elements to be measured accurately, since it presents the actual cost required to accomplish defined target objectives. Concerning Material Handling performance, particular costs that frequently get evaluated are direct labour cost, warehousing cost, inbound-outbound freight cost, or administrative costs.

Material Handling performance plays a decisive role in mutual achievement of a satisfying customer service level in the general logistics operation. Apparently, all activity-based processes incurred within Material Handling team are aimed to deliver demanded goods to customer at the right time, right place, with committed quality

conditions. Frequent measurements for logistics customer service performance are on-time delivery, handling cycle time, density of shipping errors, or general customer satisfaction level, which is often obtained through surveys and feedbacks.

As the operation in Material Handling department is mostly related to activity-based procedures, hence, productivity is another attentive factor to concentrate on.

Productivity is an uncomplicated but very useful measuring concept, it refers to the ratio between accomplished output (amount of handled shipments, for example) and required inputs (labour working hours or other involved resources). Several performance measurements of productivity in operational logistics can be mentioned are units handled per employee per hour, boxes or pallets being shipped per hour, or truck loading, unloading rates. However, there are existing difficulties in measuring productivity of certain performances in Material Handling, such as the complication of inputs associated, or the unavailability of required data for evaluation.

Quality measurements are among the most imperative demanded evaluations. Quality, nevertheless, is occasionally challenging to measure, due to its corresponding assessment. Quality performance in operational logistics activities is usually involved by several parties, not only concerned Material Handling department. Continuous goods flow needs to initially start from order receipt operated by administrative office (customer service employees), following by physical handling performance occurred in the warehouse. According to Donald J. Bowersox and David J. Closs in 1996, an ideal performance of perfect order handling should be committed the following standards: (1) complete delivery of all requested items; (2) delivery to customer's requested date with one-day tolerance; (3) complete and accurate documentation associated to the order, including packing slips, bills of lading, delivery notes and invoices; and (4) desired conditions, concerning both technical and logistical aspects. Although there are many barricades that logistic performers need to confront in order to accomplish the mentioned level of achievement, there are certain evaluations which are often applied. Those measured performances can be frequency of occurred damage, value of damaged goods, amount of customer complaints and returned deliveries, or cost of handling returned goods.

2.5 Characteristics of an ideal measurement system

The dynamic logistics operation certainly demands a reporting system that could present an overall dynamic picture of the measured performances. Goods handling output in each time unit within certain period should be feasible to be evaluated, as an example. From the obtained results, the management is able to control the working efficiency of their employees, with the intention of determining appropriate approach for potential improvements. From the fundamental logistics management point of view, a valuable reporting system should not only capture static figures of the circumstance, such as inventory level, warehouse utilization or transportation cost, but should also demonstrate the development trend over concerned period of the operation.

Required data information in an ideal reporting system should be generated and accessed within limited timely condition, due to the fact that concerned situation must be speedily and accurately analysed, so that crucial decisions can be made immediately. Desired reporting system should allow measured figures to be easily extracted, without the need of massively time-consuming calculating and analysing. Measurement system is considered to be an advantageous tool that supports the operation's performance evaluation and decision-making process.

2.6 Ideal report structure

2.6.1 Status reports

As indicated by its name, status report provides actual detailed information of concerned aspects in the operative logistics performance. It focuses to the static side of measured figures, rather to their dynamic development trend over a certain period. Status reports, however, should not be underestimated regarding their necessity and influence in controlling the existing situation. The overall instantaneous picture of measured performances is captured in status reports, which allows the relevant logistics managers to be promptly aware of ongoing condition.

Apparently, Material Handling performance is not the only field where status reports gain high-potential application in measuring and analysing the operation activities.

Status reports, on the other hand, can be applied for all other related logistics departments. In general, status reports assist line managers to approach immediate relevant information within the course of their responsibility.

2.6.2 Trend reports

Trend reports are demanded in order to present the development trend of measured performance within concerned period. While status reports display the static picture of the overall situation, trend reports, on the contrary, demonstrate the stability of interested performance and its improvement. Trend reports are considered essential in measuring and evaluating Material Handling performances, since they allow logistics managers to track the volatility of business operation, from which decisions for immediate adaptiveness are constructed.

Sustainable development of business performances is aimed by the logistics management. All the strategic decisions are usually made based on accurate information generated from trend analyses, concerning past duration. There are many affected elements for the business development could be determined by analysing trend reports, such as seasonal impact, requirement of further investment in machines or labour force, opportunities for business expansion, or timely strategic adjustment in general. Besides, trend reports also allow to produce more accurate and reliable forecasts for the business health and performance in long-term consideration, which is crucial for any sustainable enhancement. Hence, a plainly, simply and automatically generating trend reports system is highly demanded in order to gain the most conclusive insights of Material Handling performance in management of operative logistics.

3 Research implementation

3.1 Research questions

The management of any business aspect tends to seek for the most effective measurement system of relevant KPIs, which is capable of demonstrating the develop-

ment trend of business operation. Operative logistics activities are specifically generating in a dynamic and changeful circumstances, which leads to greater efforts required in order to form a competent performance measurement system. Operational logistics are executed in daily business, obligated to activities functioning and decisions making in rigorous timely manner. A practically powerful operation of physical logistics activities is expected to guarantee the achievement of fundamental requirements in logistics generally. Hence, it is more crucial for responsible logistics managers to discover what strictly needed to measure, and how to effectively display the determined figures.

The thesis work is aimed to investigate in the answers for below research questions:

1. What are the most relevant KPIs in operative logistics performance that essentially require to be measured?
2. How to implement a practical measurement system in which the chosen KPIs are displayed?
3. What are the benefits that the measurement system contributes to the management of logistic operation?

The mentioned research questions will be moderately examined through initial situation inspection, data collection and final result implementation.

3.2 Initial situation

“Creating key performance indicators will help you monitor the vital signs for your business” – mentioned by Minghini Jason, 2015, in ‘Measuring what matters’. The management of any business does not have interest in huge reports with enormous number of signs with red and green. It can happen in both negative directions, either too complicated to capture the current health of business operation, or there is a lack of addressing the most essentially critical and benefitted indicators. In fact, there are organizations who are struggling with their own performance measuring system, which leads to dissipation of effort for measuring meaningless things, while Hirschmann Automotive is not an exception. Moreover, inappropriate performance measuring system can result in non-immediate and inflexible decisions for adjusting and improving the current business circumstance. While in today dynamic logistic world, timely manner plays one of the most crucial elements to decide whether the operation is benefitted or not.



Figure 6. Key Performance Indicator (KPI) Board (Minghini, 2015)

From the critical point of view, the performance of Material Handling at Hirschmann Automotive was not measured in a well-structured and systematic way. It is essential to own a logistical measuring system in order to establish SMART targets for one's business, in which SMART refers to Specific, Measurable, Achievable, Relevant and Timely (Minghini, 2015).

Apparently, there is an urgent need for a measuring application system without time-consuming report creation done by numerous amounts of Excel files. Additionally, an effective data dashboard should be designed, with employee-friendly accessible characteristics being taken into consideration. Everyone in Material Handling department should be able to easily capture all the critical metrics, to be aware if the targeted goals are achievable in accordance with current conditions. After that, questions can be raised by them whether there is a need of supportive actions in order for them to reach the goals set by top management.

All in all, it is time for Hirschmann Automotive to implement a well-organized measuring system to evaluate the performance of Material Handling operation, which allows all necessary adjustments and improvements to be immediately observed and executed.

3.3 Research objectives

Firstly, the initial objective of the research is to determine and allocate suitable critical indicators for Material Handling performance at Hirschmann Automotive, which then will be used in designation for the data dashboard Qlik Sense. Definition and evaluation of chosen KPIs will be presented in detail.

Secondly, together with great support from IT perspective, the presentation of crucial operational logistics KPIs in Qlik Sense will be determined. The data dashboard allows accessed user to choose a variety of selected criteria which meets individual interest. Qlik Sense will be first implemented and put in pilot run in headquarters of Hirschmann Automotive in Vorarlberg, Austria, following by the future ambition is to carry out the application within the whole Hirschmann group, as a controlling and benchmarking tool.

Finally, as the project of implementing data dashboard Qlik Sense is not completed within the course of this thesis work, therefore, further potential developing and improving opportunities will be addressed.

3.4 Methods of data collection

According to Beamon, B. M. (1998), it is critical to adopt adequate and relevant performance criteria in order to establish an accurate analysing and controlling system for any field of business. Data collection and measures selection presented in this chapter are based on general guidelines suggested by Globerson (1985). The potential chosen KPIs are following the guidelines which concern three different aspects of the study (Beamon, 1998):

- 1) Methods of calculating the performance criteria must be clearly defined
- 2) Objective performance criteria are preferred to subjective performance criteria
- 3) Ratio performance criteria are preferred to absolute numbers, since ratios provide a comparison of two or more factors

Not only based on theoretical findings, the data was also collected through practical experiences obtained by subject-related employees at Austrian headquarters of Hirschmann Automotive. The below logistics experts, whose daily duties and responsibilities are directly concerning operational logistics activities, as well as logistics management, are interviewed in-person, in order to collect their opinions about the interested matter.

- Logistic director of Hirschmann Automotive: who is responsible for securing and optimizing logistics and planning processes within the whole Hirschmann group: planning of demand for finished goods, material requirements planning, material pro-

curement, goods receipt, provision of goods for serial production, handling of customer order; responsible for establishing and implementing the logistics strategy for achieving business objectives.

- Head of Logistics at Hirschmann headquarters in Vorarlberg, Austria: who is responsible for general logistics operation of the company's Austrian plant; in charge for following departments: Customer service and Cross company business, Material handling, Order fulfilment, Demand and Production planning, Transport and Customs.
- Team leader of Material handling department: who is responsible for operative and administrative processing of product supply and disposal; in charge of following sub-departments: Goods receiving, Production line and Put-away, Pick and Pack.
- Material handling project coordinators: who is supporting in material handling related projects.
- Leader of Goods receiving team: who is in charge for goods receiving activities.
- Leader of Production supply team: who is in charge for operation of raw materials warehouse, which supplies required materials for all production segmentations.
- Leader of Pick and Pack team: who is responsible for logistics operation within the finished goods warehouse; in charge for goods picking and packing.
- Team leader of Order fulfilment department: who is in charge for following sub-departments: Customer service, Production planning, Cross company planning, Demand planning.
- Logistics project managers: who are responsible for establishing and implementing logistics related projects in daily business.
- Shift leaders of each sub-department within Material handling operation
- Customer service employees: who are responsible in processing orders from customers; in close contact with warehousing team in order to proceed dispatchment of customer orders within strict timely manner.
- Cross company planners: who are responsible for crossed company shipments within different plants of Hirschmann Automotive group.
- Logistic process and systems integration experts: who are responsible for process optimization, automation and system integration; executives in implementing and securing of compliance with group logistics standards; supporting all company plants in implementing new or changed processes.
- Business process managers: who are responsible for supporting and improving logistics processes, in order to develop and maintain company's supply chain performance in a holistic way; developing cost-effective solutions for supply chain, warehousing management, materials handling and distribution issues.
- SAP coordinators: supporting with SAP related issues and optimizing involved processes.
- IT experts: supporting with IT related matters in implementing processes into daily business operation.

Each of individual from above mentioned parties was interviewed and asked for their opinions about which factor(s) of Material Handling activity they would be interest in assessing, monitoring and being reported. Survey template used during interviewing sessions is presented below.

Survey title: *Potential KPIs in operative logistics performance (Material handling performance related)*

Name of interviewee: ...

Job position at Hirschmann Automotive: ...

Short job description: ...

1. Are your job duties related to the operation of Material handling department?
 - Yes
 - No
2. How frequently do you work with Material handling department?
 - Daily
 - Weekly
 - Monthly
 - Only occasionally
3. Which department(s) of Material Handling do you work with?
 - Goods receiving
 - Production line supply and Put-away
 - Pick and Pack
 - All mentioned above
4. Are you satisfied with the current reported KPIs of Material handling performance?
 - Yes
 - No
 - Not applicable
5. How many KPIs for Material handling performance would you consider sufficient?
 - 0 to 3
 - 4 to 7
 - 7 to 10
 - More than 10
6. What are important characteristics for KPIs?
 - Be able to measure the outcome of a process
 - Clearly defined objective of the measurement
 - Guarantee mutual understanding for different groups of people with different backgrounds
 - Easily to be measured
 - Easily to explain the meanings behind
 - Chosen KPIs must be aligned with each other, as well as the company's goal or mission
 - KPIs must allow the capability of corrective actions whenever required
 - KPIs must enable to reward staff with good performance and motivate people to perform better
 - KPIs must enable to be reviewed and changed in accordance to dynamic growth of business
 - Other characteristics: ...
7. What is the time interval would you prefer concerning reported KPIs?
 - Hourly
 - Daily
 - Weekly
 - Monthly
 - Yearly
8. What types of delivery destination(s) are you concerning about?
 - Deliveries from Hirschmann to end customers
 - Deliveries within plants of Hirschmann group (crossed company shipments)

- Deliveries from suppliers to Hirschmann
 - Returned deliveries (from customers/ other plants to Hirschmann)
 - Free sample deliveries to customers
 - Other delivery destination: ...
9. Which aspect(s) of delivery form are you concerning about?
- Shipment types (full pallet/ mixed pallet/ single carton box...)
 - Number of transports delivered (trucks/ vans/ containers...)
 - Number of delivery notes delivered
 - Number of individual items delivered
 - Quantity of each individual item delivered
 - Volume delivered
 - Other aspect: ...
10. What type of chart for trend report do you prefer?
- Column
 - Pie
 - Line
 - Bar
 - Area
 - Other type: ...
11. Other specific recommendation for KPIs of Material handling performances: ...

Based on above described survey template, diverse opinions from people with different perspectives about the measurement and assessment of Material handling performance were collected. During the data collection progress, different viewpoints, assumptions, and judgements were observed. Each particular position definitely expresses distinctive intention about what component in the performance of Material Handling is worth making effort to measure, analyse and administer. All suggestions were studied, analysed and investigated in order to construct the outcoming result of potentially considered KPIs for Material handling performance, which is presented in the next chapter (Outcomes) of this thesis. Based on the determined outcomes of data collection and evaluation process, a set of finalized critical KPIs for the field will be established later on, which are used as based figures for the implemented data dashboard measurement system.

3.5 Outcomes

By analysing and assessing the collected data, a numerous amount of possible indicators related to Material Handling performance are constructed.

Based on the structure of Material Handling department at Hirschmann Automotive, in addition to the data collected from logistics-related staff at the company, a catalogue for possible potential performance indicators of each sub-team in the department is designed and presented in this chapter. With each individual KPI, the following characteristics will be explained:

- 1) Indicator Nr: each indicator has a unique identified number.
- 2) Name: name of the indicator.
- 3) Description: what information the indicator is able to provide.
- 4) Utilization: how the indicator can be used and reason why it was suggested.
- 5) Formula: how the indicator is calculated theoretically
- 6) Note (if applicable): attentive point(s) regarding the indicator that should be proper considered. For example, what other figures should be measured when analysing the selected indicator.
- 7) Problem (if applicable): it will be stated in this point, if there are challenges or difficulties in measuring the selected indicator, such as required data is not available. Problem is often shown why the indicator is not selected.

3.5.1 Indicators for Goods receiving

3.5.1.1 Number of Delivery Notes

Indicator Nr	1.1
Name	Number of Delivery Notes
Description	Indicates the quantity of Delivery Notes were processed in goods receipt per time unit
Utilization	Used to measure the amounts of workloads handled in Goods receiving activities
Formula	$\frac{\sum \text{delivery notes}}{\text{time unit}}$

Table 1. Number of Delivery Notes

3.5.1.2 Number of item positions

Indicator Nr	1.2
Name	Number of item positions
Description	Indicates the quantity of item positions were processed in goods receipt per time unit
Utilization	Used to measure the amounts of workloads handled in Goods receiving activities

Formula	$\frac{\sum \text{item positions}}{\text{time unit}}$
---------	---

Table 2. Number of item positions

3.5.1.3 Percentage of inspection lot

Indicator Nr	1.3
Name	Percentage of inspection lot
Description	Indicates the proportion of inspection lot required for received goods
Utilization	Used to measure the percentage in amount of received goods that need to be inspected at goods receipt
Formula	$\frac{\sum \text{pallets received that need inspection}}{\sum \text{pallets received}} * 100$

Table 3. Percentage of inspection lot

3.5.1.4 Number of suppliers

Indicator Nr	1.4
Name	Number of suppliers
Description	Indicates the quantity of suppliers that deliver goods to the facility over a period of time
Utilization	Used for supplier management
Formula	$\frac{\sum \text{suppliers that perform goods delivery}}{\text{time unit}}$

Table 4. Number of suppliers

3.5.1.5 Percentage of mixed pallet

Indicator Nr	1.5
Name	Percentage of mixed pallet
Description	Indicates the proportion of pallets arrived at goods receipt as mixed pallets
Utilization	Used to measure the effort needed in pallet handling, as well as manage order/ delivery structure from suppliers
Formula	$\frac{\sum \text{mixed pallets received}}{\sum \text{pallets received}} * 100$

Table 5. Percentage of mixed pallet

3.5.1.6 Number of single boxes

Indicator Nr	1.6
Name	Number of single boxes
Description	Indicates the quantity of single box/ package were processed in goods receipt per time unit
Utilization	Used to measure the effort needed in goods receipt handling, as well as manage order/ delivery structure from suppliers
Formula	$\frac{\sum \text{single boxes}}{\text{time unit}}$

Table 6. Number of single boxes

3.5.1.7 Other unrealizable indicators

- Weight of goods received: indicates the weight of received packages to be handled in a certain period of time. However, this indicator is difficult to measure, as not all data is recorded in the system, especially shipments come from irregular suppliers.
- Number of incoming trucks/ vans: indicates number of trucks or vans arrives at the receiving dock in a certain time unit. Unfortunately, the current system at Hirschmann Automotive is not able to record this data information. Hence, the measurement of this parameter still demands further clarification.

3.5.2 Indicators for warehousing performance

3.5.2.1 Average storage duration

Indicator Nr	2.1
Name	Average storage duration
Description	Indicates how long (on average) that an item is stored in the warehouse before withdrawal
Utilization	Used in inventory management. Essentially needed in spare parts identification and handling, as well as managing EOP (end of production) products
Formula	$\frac{360 \text{ days} * \text{Stock level}}{\text{Average consumption (in a year of 360 days)}}$

Table 7. Average storage duration

3.5.2.2 Warehouse utilization

Indicator Nr	2.2
Name	Warehouse utilization
Description	Indicates percentage of storage spaces used in the warehouse

Utilization	Used to measure the efficiency of capacity utilization in the warehouse, from which allows to evaluate the stock management or the demand situation, supports timely decisions
Formula	$\frac{\sum \text{used storage spaces}}{\sum \text{total storage spaces in the warehouse}} * 100$

Table 8. Warehouse utilization

3.5.2.3 Material movement rate

Indicator Nr	2.3
Name	Material movement rate
Description	Indicates percentage of materials without movement to the total products portfolio in a certain period of time
Utilization	Useful indicator to identify slow movers (as well as high runners), allow immediate react on sudden decreased demands on the market. Detects and avoids dead stock
Formula	$\frac{\sum \text{Materials without movement in concerned period}}{\sum \text{Total materials}} * 100$

Table 9. Material movement rate

3.5.2.4 Order picking performance

Indicator Nr	2.4
Name	Order picking performance
Description	Indicates number of orders which is picked and packed in a certain period of time
Utilization	Used to measure the effectiveness of order picking process
Formula	$\frac{\sum \text{picked orders}}{\text{time unit}}$

Table 10. Order picking performance

3.5.2.5 Number of different materials in the warehouse

Indicator Nr	2.6
Name	Number of different materials in the warehouse
Description	Specifies number of articles with different material identification codes that are stored in the warehouse
Utilization	Used in material management

Formula	\sum <i>number or material identification codes</i>
---------	---

Table 11. Number of different materials in the warehouse

4 Implementation of data dashboard Qlik Sense – Operative Logistics cockpit

4.1 Overview of Qlik Sense – Operative Logistics cockpit

The application tries to shed light onto operative logistical processes within the Hirschmann Group. In particular, Material Handling productivity is monitored.

Based on the results obtained from research process which was described in previous chapter, there are three core performances in Material Handling operation which were implemented in Qlik Sense – Operative Logistics cockpit as data-driven measurements. Those are *Handling Unit*, *Delivery*, and *Warehouse*.

The data cockpit provides measured figures concerning all plants of Hirschmann group, including headquarters in Rankweil (RW), Vorarlberg – Austria, Vsetin (VS) in Czech republic, Nantong (NT) in China, San Miguel (SM) in Mexico, Kenitra (KE) in Morocco, Tirgu Mures 1 (TM1) and Tirgu Mures 2 (TM2) in Romania. Besides, the operation of the external warehouse FK-Bischof, which is located approximately 10 kilometres away from the headquarters in Rankweil, is as well in consideration to be measured.

Not only static figures in a certain concerned period of time are computed, the measuring system also allows to perform dynamic evaluation, which presents the business development trend within its growth. Data are displayed in both numeric characters and appropriate charts, in order to supply any needs of measuring purposes.

Data implemented in Qlik Sense are generated and updated daily, connected to SAP system with MRP runs that occur every night. Hence, latest figures are always captured for the most accurate measurement and evaluation. The platform in Qlik Sense is not required for further manual analyses, on the contrary, each indicated performance measurement could be instantly extracted on request, without efforts of examination and determination. Moreover, measurement content of any chart or data

table is possible to be exported to an image, PDF file or directly to Excel for further investigation and evaluation if required.

4.2 Presentation of Material Handling's critical KPIs in Qlik Sense – Operative logistics cockpit

The number of outgoing indicators obtained from performed data collection is considerable, however, the management of operative logistics requires a solidified and observant set of KPIs, which is able to promptly evaluate the concerned expansive operation. Hence, relevant KPIs are chosen to be presented in the Qlik Sense operative logistics cockpit.

4.2.1 Handling Unit (HU)

According to SAP definition, a handling unit is a physical unit consisting of packaging materials and the goods contain on/in it. It is always a combination of products themselves and packaging materials. A new handling unit can also be created by associating from several other handling units.

The indicated handling units to be measured and implemented in Qlik Sense measuring system are listed below:

1. *Number of pallets*
2. *Number of single cartons*
3. *Number of cartons on pallets*

Those measured indicators can be filtered regarding time concerned (dates, weeks, months, years), shipping point (particular plant within Hirschmann group), and activity operation (inbound, outbound). By measuring those three performance indicators, it allows to track the workloads that Material Handling department needs to handle within a certain period of time. Additionally, the structure of handling shipments can also be determined. As an example, logistics manager is able to observe whether customer orders are in majority of full pallets or single cartons, from which one can obtain the broad understanding of task formation in operation of Material Handling.

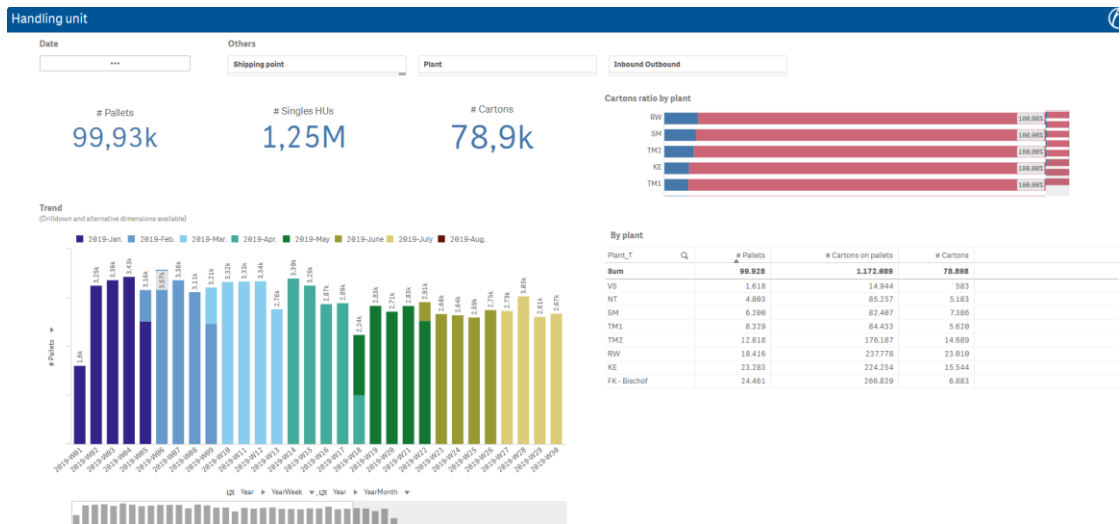


Figure 7. General overview of Handling Unit measurement

Furthermore, each particular plant within Hirschmann Automotive is able to track those three mentioned indicators (number of pallets, number of single cartons, and number of cartons on pallets) based on the selection of respectively concerned customers, external suppliers, and internal suppliers (which refers to intercompany shipments within different Hirschmann plants). Based on the development of shipment structure recorded by this measuring system, even the overall business circumstance can be shown. Number of handling units to be operated could additionally give a helpful parameter in determining and combining units of transport, which aims to the most economical and effective planning.

As in below example, the cartons ratio by each particular Hirschmann plant within the concerned period is presented. It can be seen that the number of single cartons handled is insignificant in comparison to number of cartons on pallets, which gives a positive sign in the overall business situation, as well as in Material Handling performance specifically. The picture indicates that the majority of operated shipments is distributed into full pallets loaded by cartons, only a limited number of shipments with single cartons, which demands more handling workload, is performed.

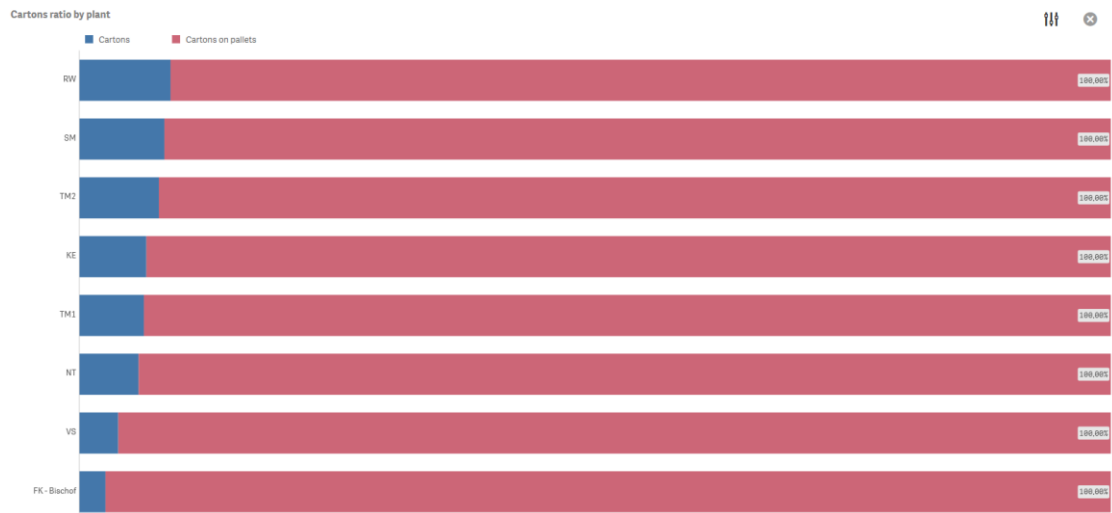


Figure 8. Cartons ratio by each Hirschmann plant

Concerning each Hirschmann plant, cartons ratio can also be measured within the plant's Material Handling operation. Below chart presents the cartons ratio in handling activities of Hirschmann's headquarters in Rankweil, Austria.

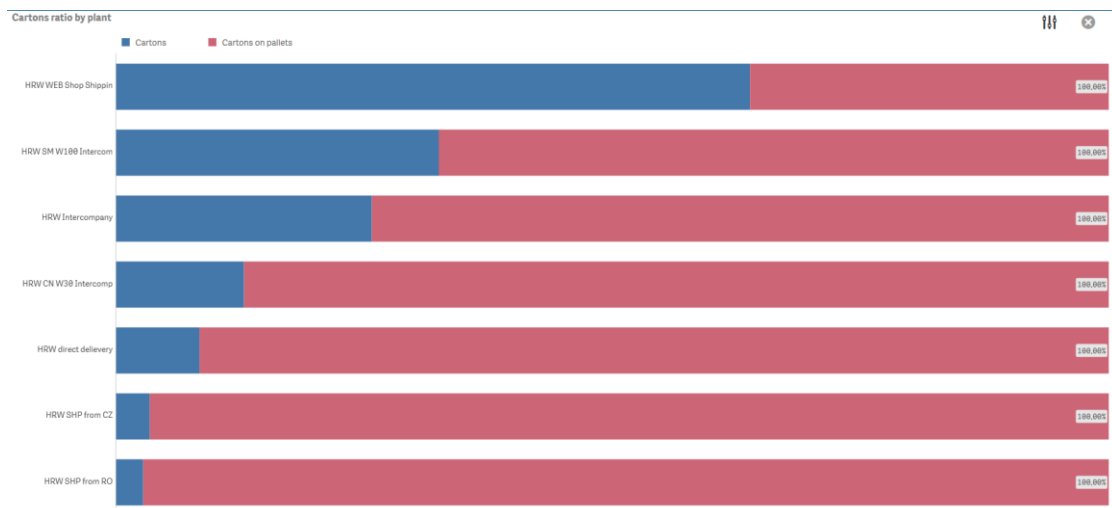


Figure 9. Cartons ratio at Hirschmann Automotive Austria

It can be seen that Web-shop Shipping orders are most likely handled as single cartons, as those orders are singular or sample orders generated through web-shop platform, by new-incoming customers. Structure of intercompany shipments (shipments to and from other Hirschmann plants) are also presented. Shipments from Hirschmann headquarters Rankweil directly to regular customers are mainly in full pallets, which is advantageous for both Material Handling operation and the overall enterprise's business.

4.2.2 Delivery

Within a certain concerned period of time, below KPIs concerning delivery were chosen to be measured and reported

1. *Number of deliveries*
2. *Number of delivery items*
3. *Delivered quantities*

Above mentioned indicators are considered as core KPIs regarding delivery consideration in performance of Material Handling operation. Those KPIs indicates the amount of shipment deliveries, as well as the variety and quantity of delivered products in handling activities. By measuring above mentioned indicators, number of customer orders handled by Material Handling team in a certain time period is evaluated.

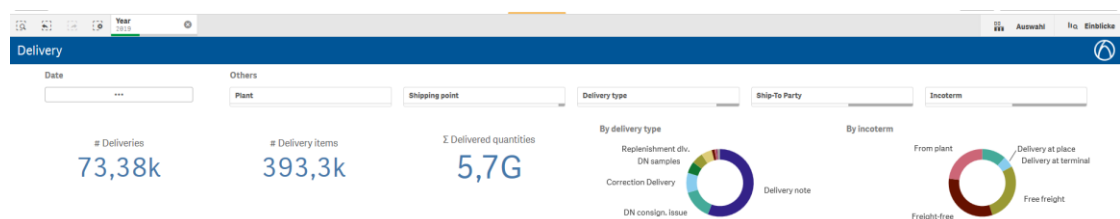


Figure 10. General overview of Delivery measurement

Similar to the measurement of handling unit, delivery measurement can also be selected based on concerned criteria, such as shipping point (particular Hirschmann plant in which the delivery is performed), delivery type (sample delivery, correction delivery, return delivery, delivery note to direct customers, delivery note for inter-company shipments to other Hirschmann plants), ship-to-party, or incoterm applied.

The measuring system allows logistics managers to track all deliveries and their diversity regarding concerned particular customers, or intercompany shipments within Hirschmann group. Based on those obtained figures, the efficiency of Material Handling operation can be evaluated. As an example, for certain customer, while number of delivered items is enormous in consideration with number of deliveries, certainly, it is required more time for Material Handling staff to handle each delivery, as they need to pick-and-pack several diverse items in order to complete a delivery. On the other hand, concerning customer orders in which the product variety is restricted, then within a certain time period, a significant amount of deliveries can be handled.

Below is an example of the top-15 ship to party with the most colossal number of deliveries performed from January to October 2019.

Delivery			
By ship to party			
Top 10			
Q	# Deliveries	# Delivery items	Σ Delivered quantities
Gesamtwerte	24.745	92.012	1.562.816.242
Magna Mirrors GmbH & Co. KG	3.239	4.177	25.990.882
HELLA GmbH & Co. KGaA	2.151	9.187	51.124.443
Daimler AG	874	2.801	649.056
Hella Electronics Corporation	740	1.728	5.311.444
Hirschmann Kenitra sarl au	736	3.728	21.755.537
BMW AG	611	1.947	1.431.262
Hirschmann Automotive GmbH	603	13.727	530.918.879
Hirschmann (Nantong)	503	2.547	139.356.510
Hirschmann Romania S.R.L.	503	5.944	21.384.212
Hirschmann Automotive Mexico	452	2.260	191.035.060
DIS Dräxlmaier Industrial Solutions	318	473	2.793.127
Yazaki Romania S.R.L.	309	2.090	43.971.378
Yazaki Europe Limited	265	1.386	10.983.278
Yazaki Saltano de Ovar	258	507	14.925.540
Yazaki Wiring Technologies	238	1.066	22.895.069

Figure 11. Deliveries by ship to party

It can be seen from obtained figures above, that essential key customers, which influence the majority of shipment deliveries are determined. This measurement plays a decisive role both in delivery activity management and customer relationship management, within the crucial focus of logistics administration. Comparing the demand situation of two leading customers – Magna Mirrors GmbH & Co.KG and HELLA GmbH & Co. KGaA, as an example. Within concerned period of time, Magna Mirrors has the biggest number of deliveries (3.239 deliveries in total), following by HELLA with 2.151 deliveries at the second place. However, the variety of delivered items demanded by HELLA (9.187) has overly doubled the corresponding figure from Magna Mirrors (4.177). In this particular circumstance, therefore, it is required greater workforce to handle orders received from HELLA than it actually is considering requirements from customer Magna Mirrors, although demands from Magna Mirrors are more considerable.

The above described case is an example of crucial business situation that needs to be recognized, as it is able to explain the demanded workload of delivery activities in consideration with customer order structure. Logistics managers ought to be aware of this trend through business development, so that decisive actions could be timely created regardless delivery inconstancy and complexity.

The measuring system in Qlik Sense allows warehouse manager to have access on delivery status of particular chosen customer, within concerned timeframe. Below figure displays the complete picture of delivery situation exclusively allocated to one of the most valuable customers of Hirschmann Automotive, Daimler AG. All concerned deliveries are shipped from Hirschmann headquarters in Rankweil, Austria in 2019 (year-to-date, August 2019). Number of deliveries, number of variably delivered items, as well as delivered quantities are recorded. Moreover, development trend of each mentioned indicator through the current year can also be shown, for example, below bar chart indicates total monthly delivered quantities to customer Daimler AG. It is observable, that Daimler AG has the most enormous demands in May and July, which should be for-seen in advance so that labour resources can be arranged sufficiently for those months, as a number of employees is expected to be on summer vacation leave.

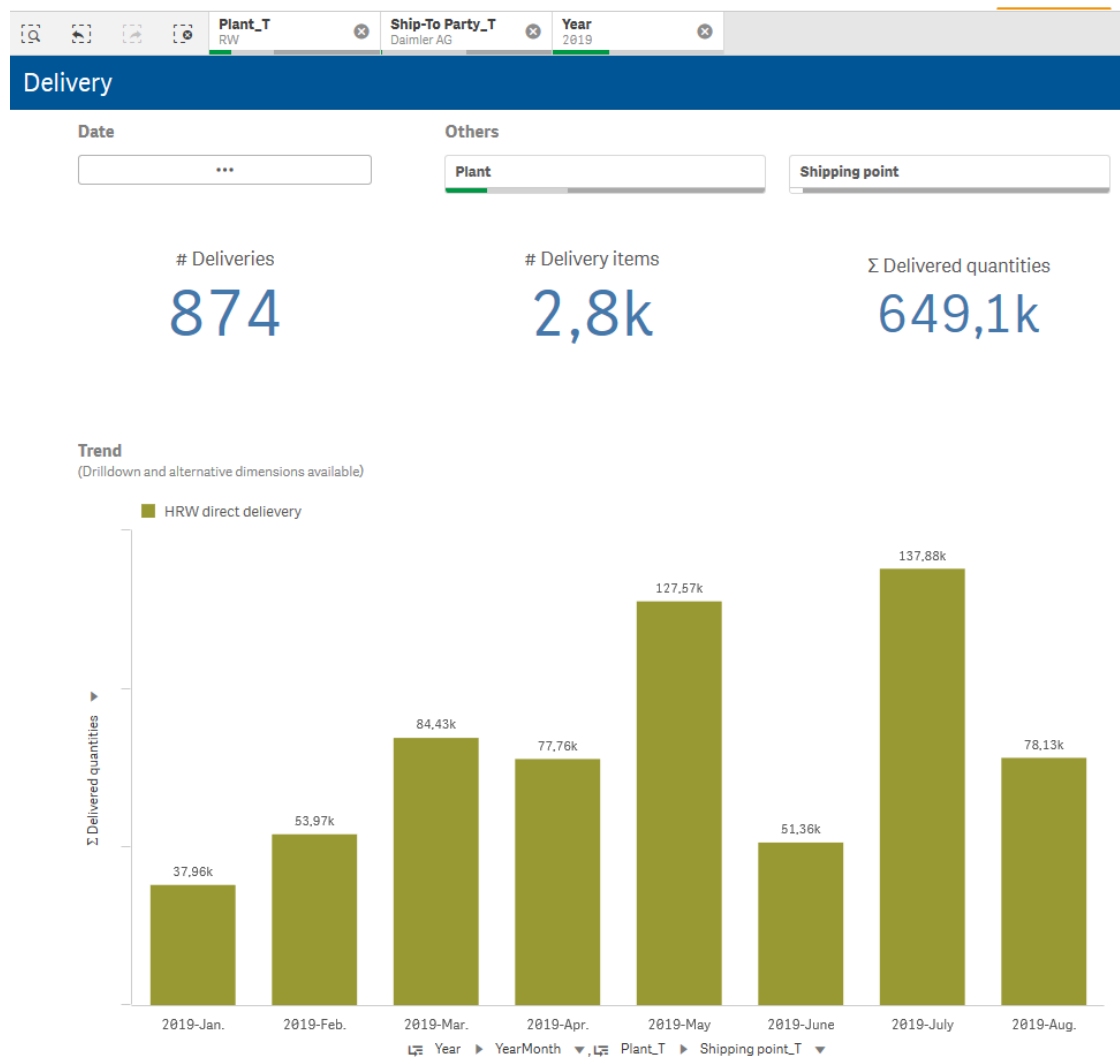


Figure 12. Delivered quantities to customer Daimler AG in 2019 (year-to-date)

Below figure contains a bar chart which presents the variety of delivered items to Daimler AG. It is noticeable, that orders in July are the most diverse in product variety, with 452 individual delivered items. Respectively, Daimler AG also has highest demand in July, with almost 140 thousand product units delivered.

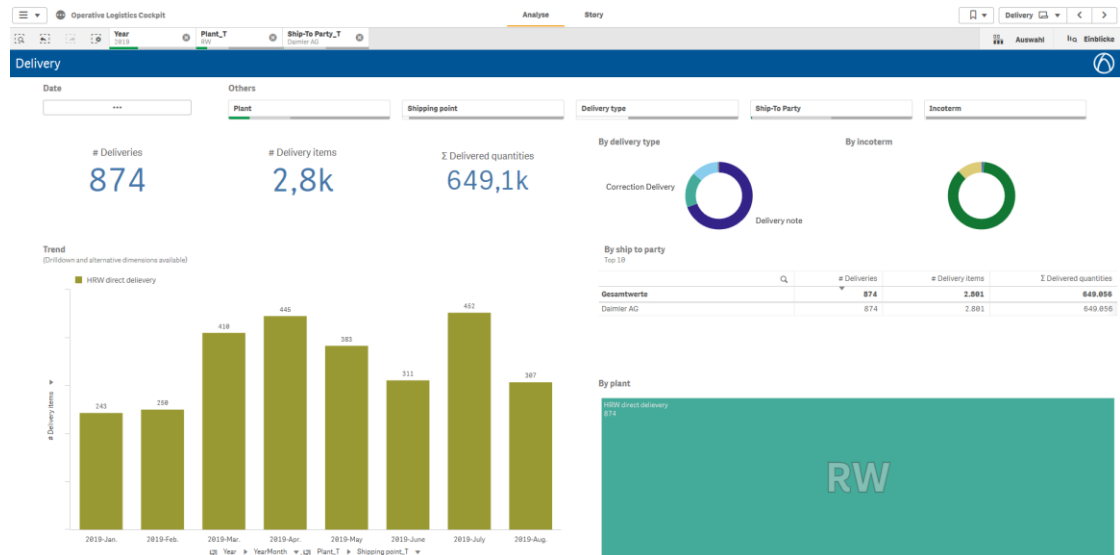


Figure 13. Number of delivered items to customer Daimler AG in 2019 (year-to-date)

Additionally, delivered shipments can be distinguished by delivery type or by incoterm applied, which are displayed in doughnut chart above, as an example. Most deliveries are regular shipments with delivery note, while there is a partial quantity of other delivery types, such as correction delivery, which is needed in cases of difference in cumulative delivered quantities within scheduling agreements, or sample delivery, which refers to free-of-charge delivery of sample products. Common shipments delivered to Daimler AG are followed FCA (Free Carrier) incoterm, as initially agreed in the contract, however, there are exceptional cases in which shipments are sent with DAP (Delivery At Place) or DDP (Delivered Duty Paid) incoterm. Possible reason for the need of those shipments could be late delivery caused by Hirschmann Automotive, which leads to special freight that Hirschmann must bear the expense. Those situations ought to be clearly determined and analysed, so that effective solutions can be formed to minimize number of shipments delivered by special transport. Within the course of Qlik Sense measuring system, not only customer deliveries are concerned, but crossed company shipments within different plants of Hirschmann

Automotive group are also put in appropriate consideration. Hirschmann Automotive headquarters in Rankweil, Austria plays a role as the centre hub of the internal supply chain. Regular shuttles, trucks and containers are shipped weekly to other Hirschmann plants. On the other hand, Rankweil plant also receives routine shipments from plants in Morocco (Kenitra), Czech Republic (Vsetin), and Romania (Tirgu Muret). Handling activities required for crossed company business are not less demanded in comparison to amount of workload needed to handle direct customer shipments. As can be observed from following figures, that chosen KPIs, which are number of deliveries, diversity of delivered items, and delivered quantities, are going to be measured, concerning crossed company shipments from Hirschmann headquarters in Austria to the plant in China (Nantong).

From January to middle of August 2019, there are in total of 503 deliveries being shipped from Austria to China, with approximately 2500 different individual products, those shipments altogether generate about 140 million product units delivered. The majority of delivered shipments is regular crossed company delivery, while there is a limited amount of distributions that belongs to other delivery type, such as sample delivery or initial delivery for new coming projects. Classifying by incoterm, most deliveries are under the application of FCA incoterm, as they are regular weekly sea freight containers. However, there are certain deliveries that need to be shipped by air freight, with DAP or DDP incoterm. Those shipments are either urgently required for initial phase of newly formed projects, or instantaneous demands from customers.

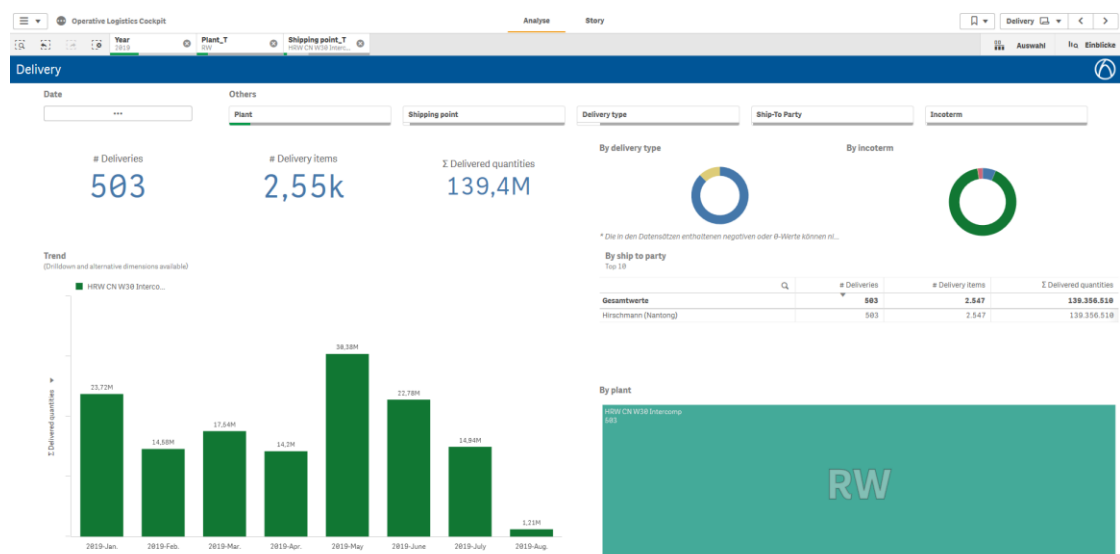


Figure 14. Delivered quantities to Hirschmann Nantong plant in 2019 (year-to-date)

Above bar chart presents the total quantity of product units that are handled for delivery to Hirschmann China in 2019 (year-to-date, August 2019). A massive quantity of approximately 30 million item units was delivered in May. Generally, demands in summer are relatively high, as well as demands in January, which are affected by winter holiday in Austria in December of previous year.

Concerning total number of deliveries which can be observed in below bar chart, there are 81 deliveries being performed in May, which respectively explains the huge amount of product units delivered in this month (around 30 million product units, figure 14). However, considering mentioned figures for March, in which the highest number of deliveries is recorded (85 deliveries), while there are only 17,5 million product units being shipped correspondingly. Certainly, the amount of ordered items in March were split into large numbers of individual deliveries, which demands greater workload in handling for warehouse operation.

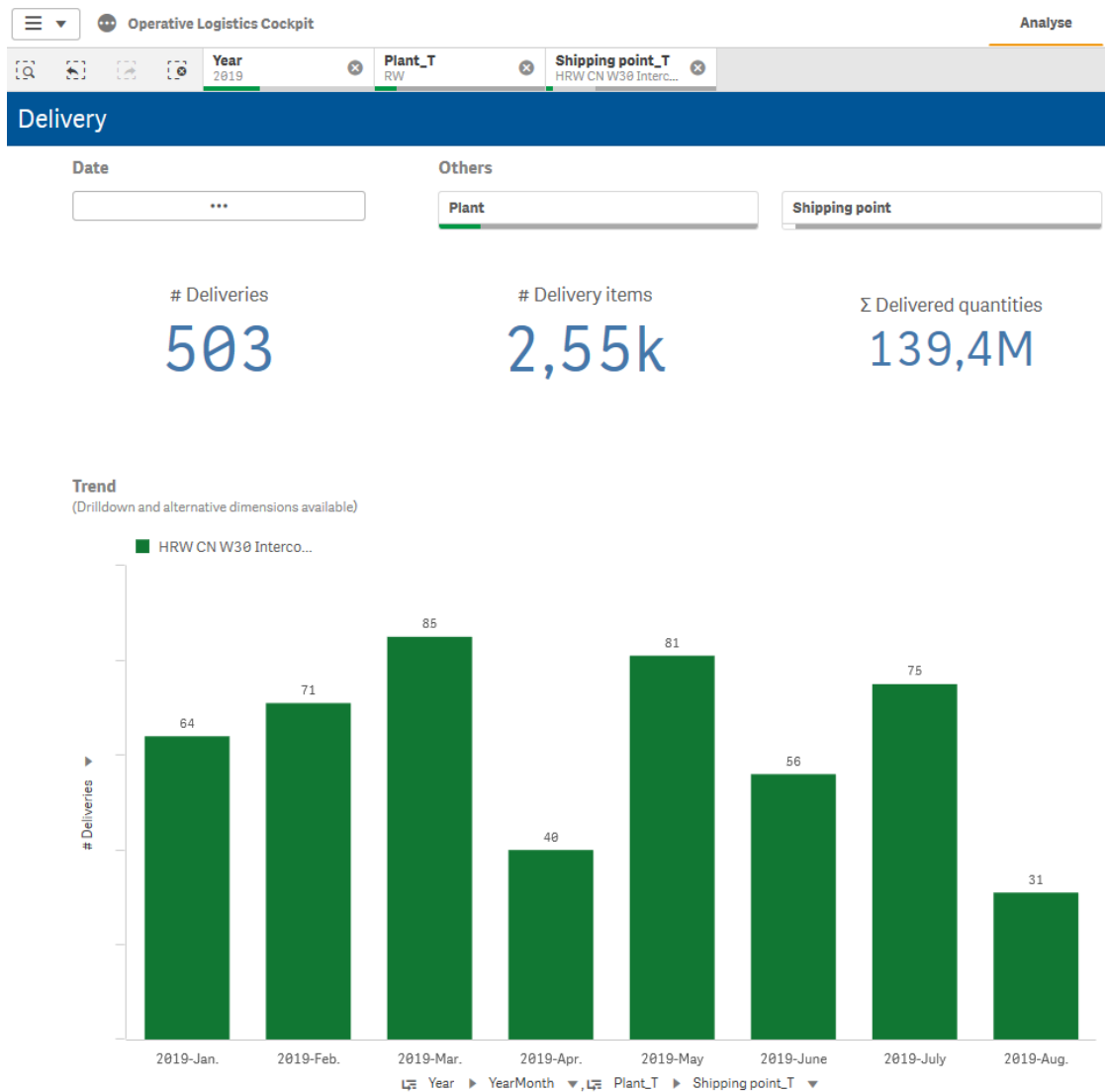


Figure 15. Number of deliveries to Hirschmann Nantong plant in 2019 (year-to-date)

Figure below demonstrates the variety of delivered items considering crossed company shipments to Hirschmann China. During those months in which the demands have high sense of product diversity, it is respectively required additional handling in delivery preparation. As each individual product comes with particular standardized packaging, the more diverse demand, the greater handling time is needed.

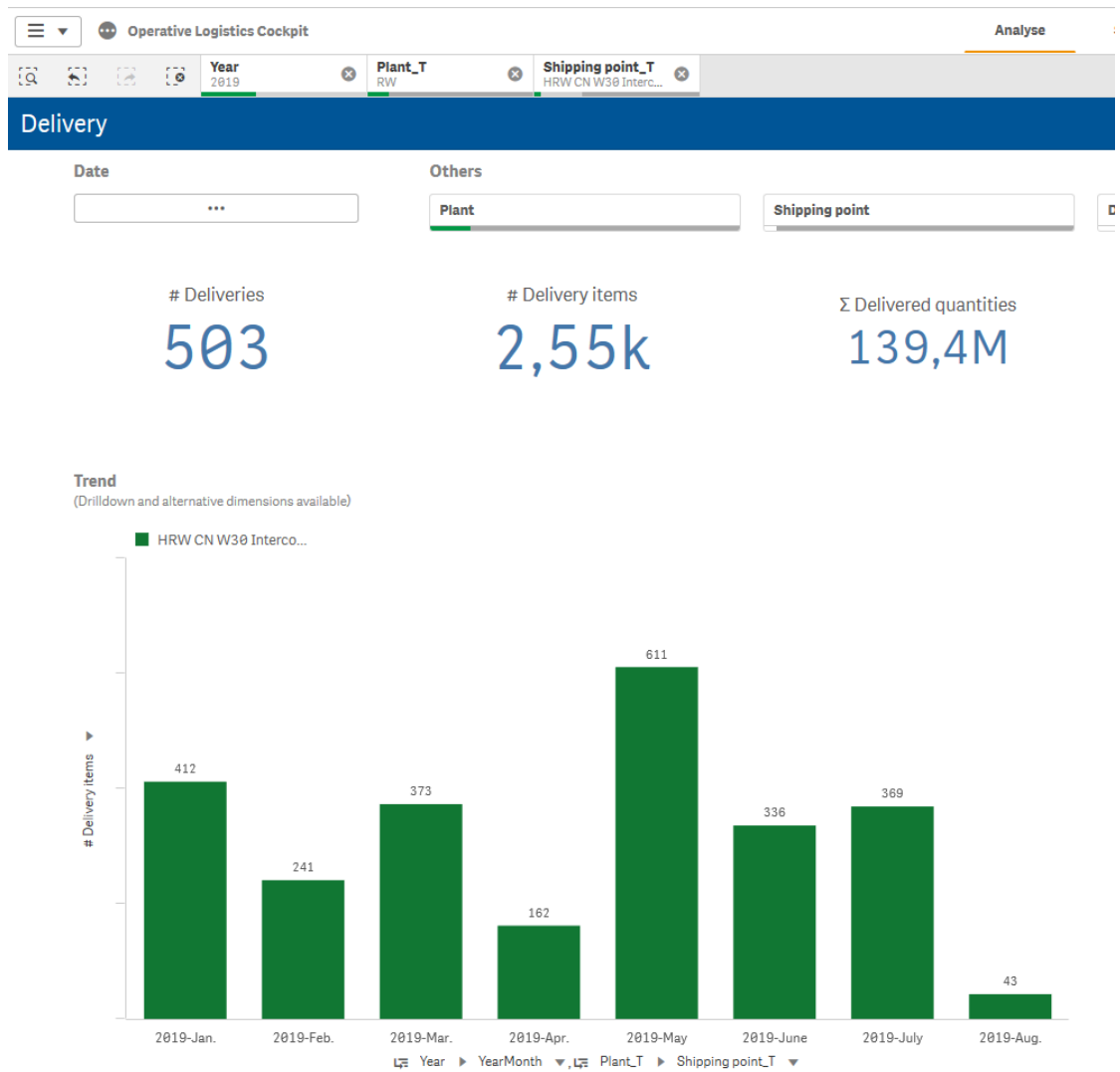


Figure 16. Number of delivered items to Hirschmann Nantong plant in 2019 (year-to-date)

4.2.3 Warehouse performance

Two KPIs were chosen in order to evaluate the performance of goods movements within warehouse operation, those are presented below:

1. *Number of transfer orders*
2. *Number of transfer order items*

The reason for this determination is that, those mentioned KPIs benefit to place the main focus on executing goods movements in the warehouse, which is the central activity of Material handling operation.

According to general definition by SAP, transfer orders refer to both logical and physical movements of goods or stock changes, including picks, putaways, posting

changes, repacking and inventory. Mainly, a transfer order contains all the information required to execute the physical transfer of materials into the warehouse, from one storage bin to another storage bin within the warehouse, or out of the warehouse. Additionally, it is also a tool to manage logical stock transfers. A transfer order is completed, for example, when goods are released from incoming quality inspection and moved to storage location, or when goods are discharged from storage location and transferred to production in order to produce other products. As transfer order identifies goods and quantity should be move, as well as source and destination storage bin of the defined movement, measurement of transfer order helps to evaluate efficiency of goods handling within the warehouse. Furthermore, based on the measurement of number of transfer orders performed in a certain period of time, it is possible to determine the crucial section in the warehouse, where it consists the most time-consuming goods movement types, as well as the busiest storage location.

By measuring and monitoring performed transfer orders, it contributes a detailed insight from the most minor movement activities occurring within the warehouse operation. From the fundamental management point of view, not only the broad picture of business performance should be captured, but an effective measuring system should also be able to track scaled-down concerning aspects, whenever it is needed. Material handling manager, therefore, will promptly obtain both broad and particularized view regarding general operation of actual goods movement inside the warehouse, which is essential in daily management, and process of developing potential adjustments.

The presentation of these two KPIs for warehouse performance are displayed in Qlik Sense with the categorisation by certain criteria, which are chosen Hirschmann plant, concerned period of time, selected warehouse, storage location, and storage type. With the defined filter selection, it is allowed to promptly track the concerned performance of focused warehouse operation regarding physical movement activities. Team leader of each warehouse segmentation is also able to take fully control of the team's productivity in regular basis.

Below figure presents the overall display of chosen KPIs in warehouse performance of Hirschmann headquarters Austria, from January to August 2019. As it can be seen,

during the mentioned period of time, there are more than 116 thousand transfer orders completed, which consists of nearly 200 thousand transfer order items. This amount of physical goods movements is occurred in three different warehouse areas of Hirschmann Austria, which are raw materials warehouse, semi-finished goods and finished goods warehouse, and external warehouse. Raw material warehouse is the warehouse section where raw materials are stored. Those materials could either be Hirschmann self-produced materials or purchased materials from external suppliers. They will be used in different production segmentations in order to produce other finished products. On the other hand, there is another warehouse area which is determined for semi-finished and finished products. While semi-finished goods are sent to other Hirschmann plants for further production of various final products based on local market needs, finished goods will be delivered directly to Hirschmann’s customer locations. Besides, the mentioned external warehouse is as well as designed for finished goods, due to the limited capacity of the main warehouse. Depending on particular concern when measuring number of transfer orders and number of transfer order items, performance in any above mentioned warehouse area can be selected.

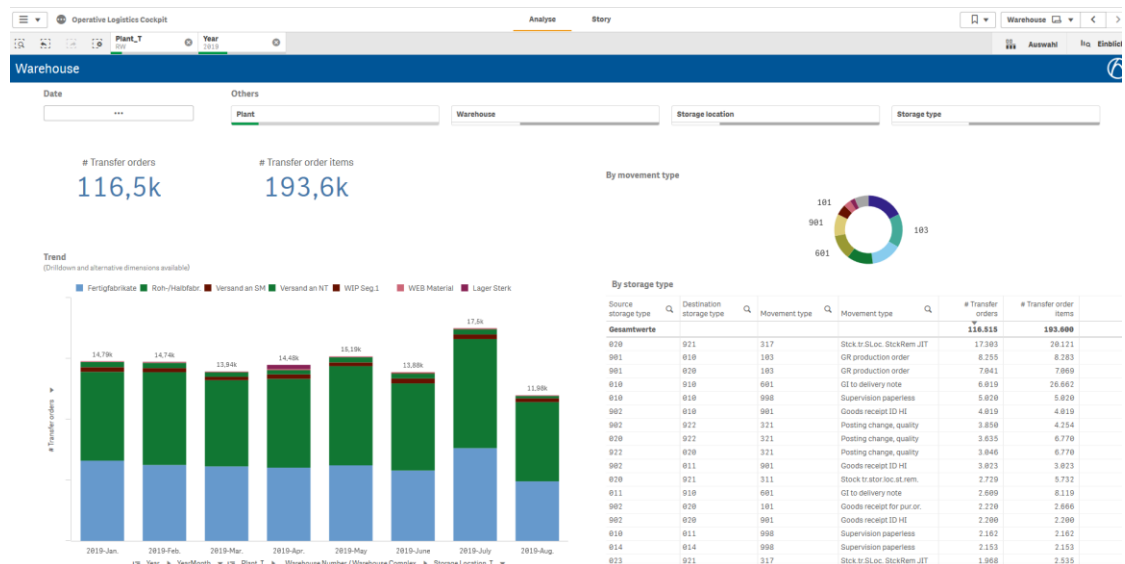


Figure 17. Number of transfer orders and number of transfer order items

The above bar chart in figure 17 represents number of transfer orders completed monthly by the warehouse performance of Hirschmann Austria, categorising by storage location. Presented storage locations are finished goods storage (Fertigfabrikate), raw materials storage (Roh-/halbfabr.), storage for exclusive distribution to

Hirschmann San Miguel in Mexico (Versand and SM), storage for exclusive distribution to Hirschmann Nantong in China (Versand an NT), storage for web-shop products (WEB material), and external warehouse storage (Lager Sterk). It can be obtained from the bar chart, that the number of transfer orders completed is relatively stable during the concerned period of time, although the highest performance is captured in July 2019. Additionally, the main focus of management should be placed on storage locations for finished goods and raw materials, where the majority of transfer orders are handled.

As the fundamental purpose of measuring and monitoring number of transfer orders and number of transfer order items is to achieve a detailed insight of physical goods movements which are operated in the warehouse, therefore, it is essential to concentrate on particular storage type, corresponding with certain goods movement type. Transfer orders can be executed in numerous amount of different movement categories, each is defined by the physical movement of goods from the specific source storage type to the destination one.

Operative Logistics Cockpit Analyse

Plant_T RW Year 2019

Warehouse

By storage type

Source storage type	Destination storage type	Movement type	Movement type	# Transfer orders	# Transfer order items
Gesamtwerte				116.515	193.600
020	021	317	Stck.tr.SLoc. StckRem JIT	17.303	20.121
901	010	103	GR production order	8.255	8.283
901	020	103	GR production order	7.041	7.069
010	910	601	GI to delivery note	6.019	26.662
010	010	998	Supervision paperless	5.020	5.020
902	010	901	Goods receipt ID HI	4.019	4.019
902	922	321	Posting change, quality	3.850	4.254
020	922	321	Posting change, quality	3.635	6.770
922	020	321	Posting change, quality	3.046	6.770
902	011	901	Goods receipt ID HI	3.023	3.023
020	921	311	Stock tr.stor.loc.st.rem.	2.729	5.732
011	910	601	GI to delivery note	2.609	8.119
902	020	101	Goods receipt for pur.or.	2.220	2.666
902	020	901	Goods receipt ID HI	2.200	2.200
010	011	998	Supervision paperless	2.162	2.162
014	014	998	Supervision paperless	2.153	2.153
023	921	317	Stck.tr.SLoc. StckRem JIT	1.968	2.535
014	910	601	GI to delivery note	1.602	2.477
901	013	103	GR production order	1.382	1.394
013	910	601	GI to delivery note	1.377	5.114
901	922	321	Posting change, quality	1.269	1.417
902	021	901	Goods receipt ID HI	1.222	1.222
010	922	309	Posting change, general	1.142	2.416
902	021	101	Goods receipt for pur.or.	1.098	1.110
021	921	317	Stck.tr.SLoc. StckRem JIT	1.050	1.138
902	013	901	Goods receipt ID HI	1.017	1.017
901	011	103	GR production order	843	886
021	910	261	GI to order	824	1.639
020	910	601	GI to delivery note	793	4.520
014	012	998	Supervision paperless	691	691
902	011	101	Goods receipt for pur.or.	686	707
021	921	311	Stock tr.stor.loc.st.rem.	675	1.456

Figure 18. Storage type categorisation of number of transfer orders and number of transfer order items

Due to the general business volatility in automotive industry, the amount of required goods movements in the warehouse can be fluctuated in a short period of time, following by overall demands situation. As an example, figure 19 below presents the number of transfer orders completed weekly in each particular storage location in August 2019. It can be seen that the measured figure varies significantly within a very short concerned period of time.



Figure 19. Number of transfer orders in August 2019 sorted by warehouse type

From above figure, it can be observed that the greatest fluctuation of number of transfer orders handled belongs to goods movements of finished goods (Fertigfabrikate), which apparently says that it needs more focus to determine the optimal number of warehouse employees to handle movement flow of finished products, than raw materials. By measuring and assessing this amount of transfer orders regulated in the warehouse, order fulfilment team is also capable of noticing the inconstancy in customer orders of finished products, which requires an immediate intention and investigation to react. In this particular example, all orders from major valued customers must be reviewed, customer service employees must promptly get in contact with customers in case of any short-term significant decrease in customer's demands.



Figure 20. Number of transfer orders in 2019 (from January to August) handled by all storage locations

Figure 20 above represents the number of transfer orders handled by the warehouse of Hirschmann Austria, concerning all existing storage locations, from January to August 2019. The figures can also be sorted by particular interested storage location, for more compact insight into each individual storage component of the warehouse operation. As an example, transfer orders handled by finished goods storage (Fertigfabrikate) is assessed below.

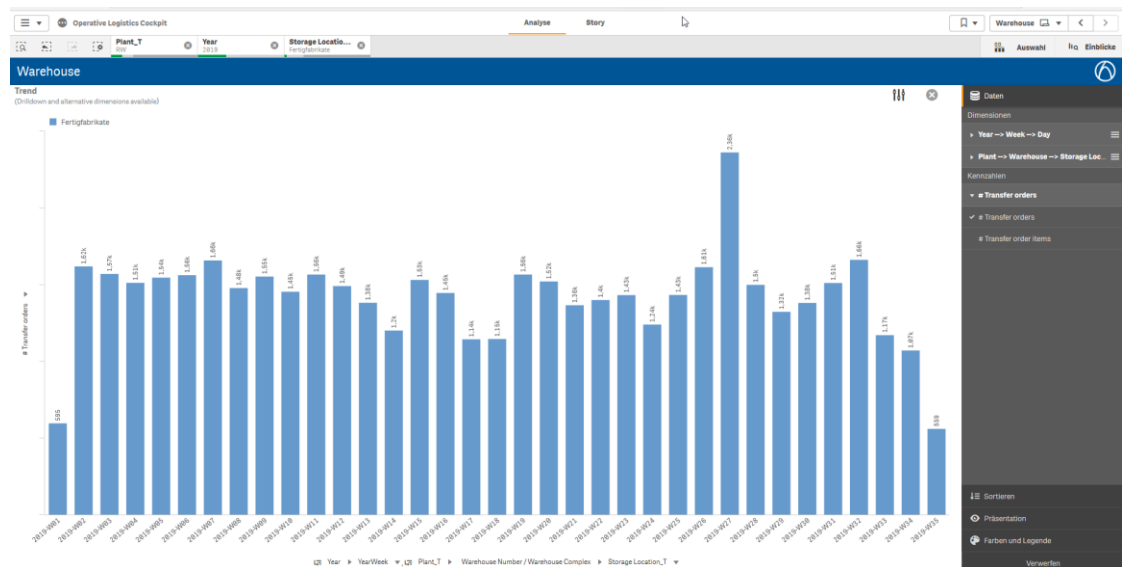


Figure 21. Number of transfer orders for finished goods in 2019 (week 01 to week 35)

To emphasize the importance of trend report for any business chosen KPI, figure 21 above presents the development trend of number of transfer orders handle within finished goods storage of Hirschmann Automotive in 2019 (from week 01 to week 35). It can be effortlessly seen that the peak of handled transfer orders applies for calendar week 27, respectively being the first week of July. Considering the general circumstance of automotive industry, this sign can be explained. In order to prepare for the summer closure, which is normally in July, a majority of automotive manufacturers tend to increase their demands in advance, to ensure the sufficient amount of required goods for their temporally summer shut down. Hirschmann Automotive as a supplier, thus, will eventually receive increased demands of finished products from its customers. The warehouse manager should be able to fore-see the incoming situation, for the purpose of arranging labour workforce to handle the peaked amount of transfer orders for finished goods during this particular period of time.

The similar theory is applied to number of transfer order items, which emphasizes the actual physical amount of items to be handled within warehouse operation.

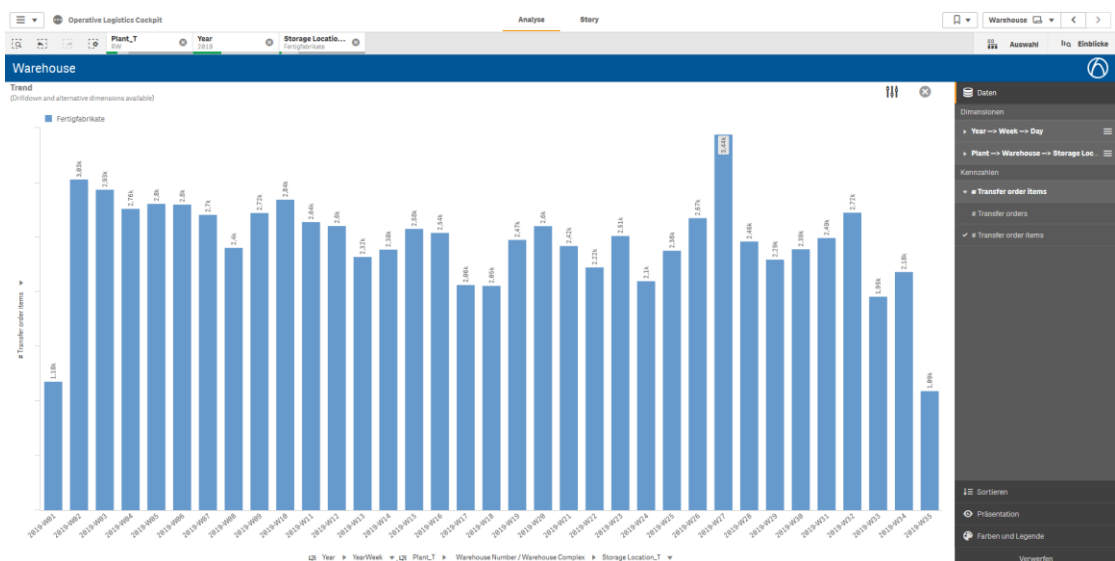


Figure 22. Number of transfer order items for finished goods in 2019 (week 01 to week 35)

5 Discussions

5.1 Research results

The formation of operational logistics indicators system is essentially demanded in order to build a company's logistics strategy, as well as maintain an effective logistics operations management. For the purpose of determining an applicable set of critical KPIs in operative logistics performance, particularly Material Handling activities, within the course of this thesis work, a research was completed based on existing circumstance at Hirschmann Automotive in Vorarlberg, Austria. Decision for chosen set of KPIs regarding different individual component of Material Handling department at Hirschmann was precisely considered, examined, consulted with experienced experts in the field.

Fundamental criteria for the election of Material Handling performance's KPIs are initially defined, as essential background to primarily commit when starting the thesis work. Defined KPIs are implemented into a data dashboard platform – Qlik Sense – a measuring system used to visualize the performance of Material Handling operation. Below KPIs are presented in Qlik Sense, as indicators that benefit to measure, monitor and control the strength of Material Handling performance at Hirschmann Automotive.

Chosen KPIs for Handling Unit (HU):

1. *Number of pallets*
2. *Number of single cartons*
3. *Number of cartons on pallets*

Chosen KPIs for Delivery:

1. *Number of deliveries*
2. *Number of delivery items*
3. *Delivered quantities*

Chosen KPIs for Warehouse performance:

1. *Number of transfer orders*
2. *Number of transfer order items*

Determined KPIs are designed to measure and evaluate the outcomes of the concerned process within Material Handling operation. Each interpreted KPI serves purposefully the mutual goal of managing concerned logistics performance. In addition to the user friendly designation of Qlik Sense, it visualizes the overall picture of physical activities' efficiency occurring within the department. Logistics managers of Hirschmann Automotive, therefore, are able to promptly follow not only spontaneous performance of Material Handling department at a short time period, but also the development trend during the long term. Figures generated by Qlik Sense are used in regular managerial responses to the business progress.

Besides the purpose of managing the accomplishment of Material Handling division, described KPIs additionally support other departments, Order Fulfilment for example, in observing the enhancement direction of associated business aspect. Customer behaviours in generating demands could be recognized through assessing the workloads that Material Handling department must conduct within the concerned period of time. Warehouse management, especially, could obtain great benefit from evaluating and controlling the measured KPIs, which supports in concluding with any decision for changes or adjustments.

5.2 Application in shop-floor meetings and reflections

At Hirschmann Automotive, each department regularly holds weekly shop-floor meeting within each individual team of the department. Shop-floor meetings are designed for the purpose of instantaneously updating and reviewing the on-going business situation internally, especially essential for the management to promptly capture the extensive picture of the team's operation. The presentation of chosen KPIs obtained from Qlik Sense, plays an excellent role in contributing to the most effective and optimal data preparation for shop-floor meetings, which not only Material Handling department could benefit from, but also Order Fulfilment division. Concerned figures could easily be extracted from Qlik Sense within insignificant time, and visualized with appropriate type of charts at one's preferred reference.

Chosen KPIs for Handling Unit (*Number of pallets; Number of single cartons; and Number of cartons on pallets*) broadly display the form of received customer orders.

By measuring and presenting these figures during shop-floor meetings, it is able to effortlessly detect those customers whose orders are with low volume but high variety of products, for example. Greater workload, therefore, is demanded to handle this type of customer order. Material Handling team should primarily arrange sufficient staff to handle physical goods movement in the warehouse, on the other hand, customer service employees from Order Fulfilment team could get in contact with each particular customer to re-negotiate terms concerning their current order form, which aims to more optimal business bargain. The similar idea is applied for chosen KPIs for Delivery (*Number of deliveries; Number of delivery items; and Delivered quantities*).

Chosen KPIs for Warehouse performance, which are *Number of transfer orders* and *Number of transfer order items*, place the focus on actual goods movements occurring within warehouse operation. Hirschmann Automotive owns a high-complexity warehouse structure, which insists variety of material movement types amidst different storage locations, such as raw materials storage, finished goods storage, crossed company materials storage, and external warehouse. Hence, it is necessary to quickly observe and monitor the intensity of physical movements handled in each individual warehouse element. Based on obtained KPIs, warehouse managers are able to define fine planning regarding labour force, machine and other infrastructures. Furthermore, by capturing the development trend of determined KPIs, it can be used as an advantageous background information in order to form potential investment for the warehouse's operation in the long run.

Additionally, the chosen set of KPIs is considered relevant and purposeful not only for Material Handling management, but for also Logistics processes management in general. With the excellent support of IT department in the implementing and developing phase of the data dashboard Qlik Sense, defined critical KPIs are able to be downloaded, extracted and assessed rapidly, without the need of manually creating time-consuming reports. Qlik Sense is qualified for an appropriate performance measuring tool, that the management of related business aspects could comprehensively benefit from.

5.3 Limitations and further development in the future

Despite the profitable application of the implemented data dashboard Qlik Sense in measuring and monitoring performance of Material Handling operation, there are always rooms for improvement. With the background of current research, in the future, there is the possibility to measure each mentioned KPI per warehouse employee, for example, number of transfer orders that each employee is able to handle in one hour. The idea could provide logistics managers a detailed and precise accuracy of the performance's effectiveness. Nevertheless, it will consequently require more background efforts in order to make the measurements applicable.

As logistics world, which includes Material Handling operation, is a dynamic and fast-transformed business in general. Determined critical and purposeful KPIs at the current moment of time might not be applicable to the circumstance in the future. For that reason, it is essential to understand and expect potential adaptations that might come. Respectively, there is a possibility that the current collection of KPIs for Material Handling performance may not be relevant at a certain point of time. Further research might be required repeatedly in order to endure with the latest logistics industry occurrence, as it is the natural growth of any developing business.

References

- Ali, M.;& Murshid, M. (2016). Performance Evaluation of Flexible Manufacturing System Under Different Material Handling Strategies. *Global Journal of Flexible Systems Management*, 287-305.
- Bairagi, B.;Dey, B.;& Sarkar, B. (2013). Bairagi, Bipradas, Balaram Dey, and Bijan Sarkar. "Incremental Analysis for the Performance Evaluation of Material Handling Equipment: A Holistic Approach. *Uncertain Supply Chain Management*, 77-86.
- Beamon, B. M. (1998). Performance, reliability, and performability of material handling systems. *International Journal of Production Research*, 377–393.
- Berk, J. (2010). *Material-Handling Improvements*.
- Bowersox, D. J., & Closs, D. J. (1996). *Logistical management*. New York: The McGraw-Hill Companies, INC.
- Chakravorty, S. (2009). Improving distribution operations: Implementation of material handling systems. *International Journal of Production Economics*, 89-106.
- Chesney, S. (2017). Use KPIs to Make Better Business Decisions: Choosing the right performance indicators for your practice can help inform your decisions and determine the health of your practice.(ON THE JOB: IN PRIVATE PRACTICE)(key performance indicators). *ASHA Leader*, 42.
- Christopher, M. (2016). *Logistics & supply chain management (Fifth edition.)*. Harlow, England: Pearson.
- Cronin, G. (2007). Measuring strategic progress: Choosing and using KPIs.(key performance indicators). *Accountancy Ireland*, Vol.39(4), p.30(2).
- Dietrich, M.;& Wald, A. (2019). Measuring business performance in the metal finishing industry by combining theory with practice. *Transactions of the IMF*, 174-181.

- Ericson Öberg, A.;Hammersberg, P.;& Fundin, A. (2017). Factors influencing control charts usage of operational measures. *Measuring Business Excellence*, Vol.21(3), pp.225-238.
- Erkayaoğlu, M.;& Demirel, N. (2016). A comparative life cycle assessment of material handling systems for sustainable mining. *Journal of Environmental Management*, 1-6.
- Faber, N.;De Koster, R.;& Smidts, A. (2018). Survival of the fittest: The impact of fit between warehouse management structure and warehouse context on warehouse performance. *International Journal of Production Research: Leading scholars in Production Research for the 55th volume anniversary of IJPR*, Vol.56(1-2), pp.120-139.
- Frazelle, E. (2002). *Supply chain strategy: The logistics of supply chain management*. New York: McGraw-Hill.
- Garg, A.;Joubert, R.;& Pellissier, R. (2004). Measuring business performance: A case study : research article.
- Ghiani, G.;Laporte, G.;& Musmanno, R. (2013). *Introduction to logistics systems management (2nd ed.)*. Chichester, West Sussex, U.K: John Wiley & Sons, Ltd.
- Golfarelli, M.;& Rizzi, S. (2007). Managing late measurements in data warehouses. *International Journal of Data Warehousing and Mining*, Vol.3(4), p.51(17).
- Green, J.;Lee, J.;& Kozman, T. (2010). Managing lean manufacturing in material handling operations. *International Journal of Production Research*, 2975-2993.
- Gudehus, T. (2009). *Comprehensive logistics*.
- Haponava, T.;& Al-Jibouri, S. (2009). Identifying key performance indicators for use in control of pre-project stage process in construction. *International Journal of Productivity and Performance Management*, 160-173.
- Horvãthovã , J.;& Mokriřovã , M. (2017). INNOVATIVE APPROACHES AND THEIR APPLICATION IN MEASURING BUSINESS PERFORMANCE. *CBU International Conference Proceedings*, Vol.5, pp.178-183.

- Jonsson, P. (2008). *Logistics and supply chain management*. Maidenhead [England]: McGraw-Hill Higher Education.
- Josh, P. (2010). Key performance indicators.(Business Insights). *ANSOM (Army, Navy, Supplies, Outdoor Merchandise)*, Vol.65(3), p.10.
- Kim, S.;& Nussbaum, M. (2013). Performance evaluation of a wearable inertial motion capture system for capturing physical exposures during manual material handling tasks. *Ergonomics*, 314-326.
- Lam, H.;Choy, K.;Ho, G.;Cheng, S.;& Lee, C. (2015). A knowledge-based logistics operations planning system for mitigating risk in warehouse order fulfillment. *International Journal of Production Economics*, Vol.170, pp.763-779.
- Levans, M. (2019). Merchandise returns system facilitates reverse logistics. 3-5.
- Malini Natarajarathinam, M.;& Michael, D. (2011). Measuring performance of material handling systems: a conveyor system analysis. *Int. J. of Business Performance and Supply Chain Modelling*, 167-180.
- Mangan, J.;Butcher, T.;& Lalwani, C. (2008). *Global logistics and supply chain management*. Chichester, England : Hoboken, NJ: John Wiley & Sons.
- Minghini, J. (2015). Measuring what matters. *Material Handling & Logistics*, 18-20.
- Pletneva, N.;& Koshcheyev, V. (2015). Logistics of a Building Company: Specifics and Methods of Logistics. *Applied Mechanics and Materials*, 1013-1018.
- Rossi, D.;Bertoloni, E.;Fenaroli, M.;Marciano, F.;& Alberti, M. (2013). A multi-criteria ergonomic and performance methodology for evaluating alternatives in “manuable” material handling. *International Journal of Industrial Ergonomics*, 314-327.
- Rush, C. (2019). Getting Started with Data Analytics: Five Questions You Need to Ask. *Material Handling and Logistics*.
- Sardana, G. (2008). Measuring business performance: A conceptual framework with focus on improvement. *Performance Improvement*, Vol.47(7), pp.31-40.

- Staudt, F.;Alpan, G.;Di Mascolo, M.;& Rodriguez, C. (2015). Warehouse performance measurement: a literature review. *International Journal of Production Research*, Vol.53(18), pp.5524-5544.
- Strayhorn, L. (1997). Upgrading materials handling systems for top performance. *Industrial Management*. *Industrial Management*, Vol.39(4), p.29(3).
- Wagner, D.;& Reed, M. (2013). Step scaling and behaviour selection in a constrained set of manual material handling transfers. *Ergonomics*, 964-976.
- Waters, D. (2009). *Supply chain management: An introduction to logistics (2nd ed.)*. Houndmills: Palgrave Macmillan.
- Wudhikarn, R.;Chakpitak, N.;& Neubert, G. (2018). A literature review on performance measures of logistics management: An intellectual capital perspective. *International Journal of Production Research*, 56 (13).
- Yıldız, S.;& Karakaş, A. (2012). Defining Methods and Criteria for Measuring Business Performance: A Comparative Research Between the Literature in Turkey and Foreign. *Procedia - Social and Behavioral Sciences*, 1091-1102.

Appendices