ACTA TECNOLOGÍA

electronic journal
ISSN 2453-675X
Volume 7
Issue 2
2021

International Scientific Journal about Technologies

CONTENTS

(JUNE 2021)

Acta Tecnología - International Scientific Journal about Technologies
Volume: 7 2021 Issue: 2 Pages: 41-46 ISSN 2453-675X

doi:10.22306/atec.v7i2.104 *Received: 09 Nov. 2020; Revised: 10 Mar. 2021; Accepted: 06 Apr. 2021*

STUDY ON THE IMPACT OF SMART AND INNOVATIVE DELOCALIZATION PRACTICES ON INTERNATIONAL TRADE

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Keywords: smart delocalization, international trade, optimization, supply chain engineering
Abstract: Faced with cumulative competition linked to the globalization of markets and increasingly stringent requirements in terms of performance, many companies are led to ask the question of delocalization part or all of their activities. Delocalization or Offshoring is a strategic decision that requires companies to review and reconfigure their methods of managing operations, especially those relating to the supply chain. The work objective is based on the key factors to be taken into account for the design of the supply chain in the context of offshoring in a context of demand for innovation. First, we address the problem of defining delocalization / Smart Delocalization and Supply Chain. Then, we review the literature to define the specificities of the problem of relocations and their impact on international trade, in particular the case of Morocco, and thus identify all the factors and constraints to be taken into account during the reconfiguration of the chain. supply chain in order to adapt it to the context of the practice of smart delocalization in an innovative context.

1 Introduction

The current economic context is characterized by increasingly volatile and unpredictable demand. As a result, the business environment has changed significantly and has become more complex and more difficult to predict than ever. Companies are facing multiple challenges, in particular shortening product life cycles, increasingly fierce competitive pressure, as well as new industrial and environmental constraints. In addition, these last decades have known a very strong technological evolution in particular in the field of information and communication technologies supporting the information system. These new information and communication technologies have enabled the emergence and development of new relationships within companies as well as between these companies. They have fostered a certain functional and technical integration necessary for the globalization of markets and the globalization of competition. To ensure their sustainability, firms are led to ask the question of a partial or total relocation of their activities.

2 General context of smart delocalization

2.1 International supply chain

The supply chain has become of crucial importance in business management. It represents an operational link between the various activities of the company [1], ensuring the consistency and reliability of material flows, with a view to the quality of service to customers while allowing the optimization of resources and reduction of costs [2].

2.2 The smart delocalization

Everyone understands intuitively that delocalization means transferring production from the national territory to other countries. However, the reality turns out to be more complex. Indeed, delocalization is often confused with other concepts (such as deindustrialization, outsourcing [3]. Smart delocalization allows the intelligent use of all tools and techniques to allow the company to minimize costs while gaining the maximum for all stakeholders. From beyond that the concept of innovation appears, then that it is a question of looking for intelligent solutions of delocalization, this implies the implementation of innovative outputs.

Table 1 and Table 2 highlights a few definitions cited in the literature.

Table 1 Summarizes the different definitions found in the literature that we consider the most relevant

Author	Definition
Lee et Billington, 1993	The supply chain is a network of facilities that provides the supply of raw materials, the transformation of these raw materials into components and then into finished products, and the distribution of finished products to the customer.
Génin, 2003	A supply chain is a network of organizations or functions geographically dispersed across several cooperating sites, to reduce costs and increase the speed of processes and activities between suppliers and customers. If the goal of customer satisfaction is the same, the complexity varies from one supply chain to another.
Fulconis et al, 2009	Transversal approach planning, implementing and controlling physical and information flows from the point of consumption to the point of origin

Table 2 Definitions of delocalization

Author	Definition
Arthuis 2005	Delocalization brings together all the arbitrations carried out by companies against the location of activities and jobs in the country of origin.
Aubert et sillard 2005	It is the substitution of foreign production by domestic production resulting from the arbitration of a producer who gives up producing in the country of origin to produce or subcontract abroad.
Hammami 2008	Delocalization is the transfer by direct investment abroad of all or part of a productive process, the production of which is originally intended for the same markets as before, in order to maximize the added value of the activities of the firm.
Kinkel et Maloca 2009	Delocalization of production capacity means relocation of this capacity abroad.

Bernard et al. distinguish three types delocalization: delocalization with cessation or reduction of activity in the country of origin, i.e. the transfer to a host country of all production or a link in the production chain of goods or services with cessation of activity and / or employment in the parent company [4], delocalization with global expansion of the activity: this is the start in a country reception of a production or a link in the production chain of goods or services similar to those of the country of origin without stopping or reducing activity and / or employment and delocalization with diversification of the activity: Establishment in a host country of a production of goods or services related or not to the productions of the parent company in the country of origin [5].

The current economic situation, characterized by fierce competition, shortages in energy and raw materials, the saturation of markets, informed customers, means that companies are in search of competitive advantages allowing them to stay ahead of their local [6], national and international competitors, to ensure their sustainability [7].

The competitive advantages sought essentially revolve around two major issues cited in Table 3.

Table 3 The causes of delocalization

Optimization of production costs	Selling on the local market
Benefit from a cheaper workforce	Getting closer to consumer markets
Overcome all the constraints of western countries	Overcome various obstacles to the export (quotas, customs taxes ...) of emerging countries
Benefit from advantages offered. Some LowCost countries offer additional services to companies setting up.	Free yourself from exchange rate variations

If the negative consequences for the countries undergoing delocalization are often put forward, we forget the positive consequences on the countries which benefit from these delocalization s. This is why, a complete understanding of the problem of delocalization [8], requires to see this phenomenon from two points of view, in the countries undergoing delocalization it is necessary that delocalization allows to increase the competitiveness of companies by lowering the costs of certain intermediate consumption, losing indirect jobs and redundancies, lowering the price of consumer goods, which favours the purchasing power of households [9]. While in the host countries: The consequences are often very positive for countries benefiting from outsourcing, in particular emerging countries [10]. They allow in particular to Create new jobs, by the transfer of production centers, Allow the transfer of know-how and techniques, often necessary for relocation to succeed, gradually increase the standard of living of these countries [11].

3 Impact of smart delocalization on international trade

3.1 The design of the international supply chain

Efficient supply chain design and management enables the production and delivery of a variety of products at a low cost, of good quality and in times beyond competition [12]. Sink and al. sees that the design and management of the supply chain are aimed at obtaining the best overall performance so as to obtain better performance from each of the links in the chain [13].

Martel describes in a research work the problem of designing the supply chain as strategic, multi-criteria and complex [14].

The design of the supply chain plays the role of the determining factor of the success of the relocation. However, there are a number of aspects to take into account for the design and management of the supply chain which can be strategic, tactical or operational [15].

The choice of delocalization concerns the design of the supply chain and is one of the long-term management problems of the chain, ie deciding on the installations and the links between the installations. This results in localization / allocation problems in the supply chain.

3.2 The criteria involved in the delocalization decision

Since the beginning of the 1980s, many Western companies have chosen to relocate their factories or their supplies to countries with low labour costs in order to reduce their costs, in a verticalization approach; other companies, attracted by the importance of potential demand in emerging high-growth countries, are outsourcing in order to produce as close as possible to local markets, in a horizontalization strategy [16].

Analysis of the literature shows the existence of two approaches: the first, financial, emphasizes the profitability of investments, while the second deals with the strategic and managerial aspects of delocalization operations [17].

The financial approach makes it possible to estimate the profitability of a delocalization operation, while the risk management approach considers that the delocalization of production is based on opportunities but also on taking risks into account to avoid failure of the project [6].

3.3 Design models for the production line

In this section, a literature review of mathematical models of supply chain design is proposed in order to identify trends in the literature and issues related to the design of the supply chain.

Lambiase proposes a classification of the mathematical models existing in the literature according to four axes: Strategic decisions, economic parameters, constraints and characteristics of the models [18].

According toa research work there is no literature where all the decisions involved in strategic planning and the design of the supply chain are taken into account [19-22].

It is based on the design aspects of the supply chain to discuss the existing models and see if they are adapted to the delocalization problem. It therefore focuses on models that include the decision to locate production and distribution sites because it represents the basis of the problem of delocalization.

In this research work we study 10 models classified as follows: 1- [Arntzen & al. 1995] 2- [Huchzermeier & Cohen 1996] 3- [Jayaraman & Pirkul 2001] 4- [Vidal & Goetschalckx 2001] 5- [Verter & Dasci 2002] 6- [Yan & al. 2003] 7- [Fandel & Stammen 2004] 8- [Melo & al. 2005] 9- [Vila et al. 2006] 10- [Hammami 2008], [3,13,15,23-29].

The taxonomy in the literature of the models cited above is based on three axes: decisions, costs, constraints.

3.3.1 Decision variables

The Decisions cited in the following table are the most relevant in the context of offshoring. According to models that integrate all of these aspects are rare (Table 4).

Table 4 The Classification of models integrating decision variables

	1	2	3	4	5	6	7	8	9	10
Location of sites	√	√		√	√	√	√	√	√	√
Choice of technologies				√				√		
Relocation of capacities										
Choice of suppliers		√	√		√	√			√	√
Intermediate products		√		√			√			√
Transfer price			√				√			
Transport cost allocation		√					√			
General expenses allowance			√							

3.3.2 Cost factors

The costs are always included in the supply chain design models; a research work identified the costs relevant to the problem of delocalization. Apart from model 13, no model takes into account the cost of labour (Table 5), so the costs of stocks in transit are rarely taken into account.

Table 5 The Classification of models according to the consideration of cost factors

	1	2	3	4	5	6	7	8	9	10
Site closure										
Fixed supplier cost		√	√						√	√
Labour cost										
Fixed cost technologies				√						
Capacity cost								√		
Storage cost				√			√			√

Cost of stock in transit				√						
Site closure										
Fixed supplier cost		√	√						√	√

3.3.3 Constraints

This table (Table 6) represents the constraints imposed by the delocalized environment; we note that the models which take into account the technological constraints - which are important in the case of delocalization - are very rare in the literature. The same applies to the constraints of local content.

Table 6 Models that take into account constraints

	1	2	3	4	5	6	7	8	9	10
Technological constraints										
Supplier capacity		√	√		√	√	√		√	√
Local content			√	√						

The results of this classification allowed us to note that the majority of the models proposed seek to maximize the objective function, so we noticed that there is a rarity of models which take into account the cost of labour (Table 7), the constraints technology and delivery time:

Table 7 Results of model analysis

Decisions	**Transfer price** **Delocalization of capacities** **Allocation of overheads**	**2 models** **3 models** **2 models**
Costs	**Labour cost** **Fixed cost technology** **Stock in transit cost**	**1 model** **3 models** **3 models**
Constraints	**Technological constraints** **Local content**	**1 model** **2 models**

4 Morocco an excellent host country for delocalization and offshoring

Morocco has entered the internationally recognized outsourcing destinations, particularly in the French-speaking world. Thus, the Morocco destination is systematically considered in the majority of Delocalization decisions and reference players have trusted Morocco [17].

Being aware of the challenges of offshoring and of the opportunities generated by this wave of globalization, Morocco has taken incentive measures to attract foreign direct investment (FDI), which is an engine of growth for the national economy.

The new investment attraction strategy adopted by Morocco as part of the "Industrial Emergence Plan" promises to be a kind of redefinition of Moroccan industrial policy. This redeployment is intended to be strategic in view of the competitiveness challenges that the country is faced with following the alarming findings of the country's economic situation, which is strongly linked to industrial structures [20].

4.1 SWOT analysis of the industrial sector in Morocco

We highlight in Table 8 the factors that make Morocco an attractive platform for the relocation of industrial firms as well as the weaknesses and threats that can slow down this relocation movement.

Table 8 SWOT analysis of the industrial sector in Morocco

Strengths	Weak points
-Geographic proximity to Europe and timetable -Modernization of production tools -Flexibility to adapt to new markets -Standardization and quality approach -Quality and cost of labour	-Low importance to research and development -Difficulties in correctly using production tools -Technological delay -Delay in the transformation to globalization
Opportunities	**Threat**
-Willingness to delocalize European equipment manufacturers (Cost reduction) -Very smart customs dismantling -Creation of an automotive technical center -Upward trend in the national automobile market	-Inability to control unfair competition -Slow responsiveness to the demands of globalization and the free trade area

4.2 Discussion

Our research work goes in the direction of strengthening the position of Morocco among the target countries of the relocation of large international companies.

Our contribution will take on a technical and engineering aspect, by proposing a mathematical model for the design and optimization of the supply chain in a delocalized environment. This model will be a decision-making tool for multinationals looking to relocate their activities to Morocco, and even for Moroccan companies that are studying investment opportunities outside the national territory.

After having identified the characteristics of the phenomenon of delocalization and based on how these characteristics impact the design of the supply chain, we are led to examine the models of the supply chain existing in the literature and see if these models are well suited to context of delocalization.

With this in mind, we have reviewed the analytical approaches to supply chain design as well as the classification of existing models according to well-defined axes of analysis. This classification allowed us to identify the model that best takes into account aspects of delocalization.

In perspective, we plan to verify and improve this model by adding relevant factors to take into consideration when designing the supply chain in the context of delocalization.

5 Conclusions

One of the major challenges for companies is to contribute to growth by helping to re-establish the relocation of some of the company's activities. The Challenge consists in creating conditions that promote long-term competitiveness capable of bringing in innovative solutions. Delocalization leads to an increasingly complex industrial organization. It is therefore important to consider the company beyond its usual structure, taking overall account of its suppliers and customers. Delocalization or smart Delocalization innovations are multiplying and competition is becoming increasingly fierce.

The problem relates to the modelling of the logistics chain in the context of delocalization for optimized management.

This study allowed us to perceive the importance of offshoring today and its issues that must be studied in depth, we established a state of the art to understand the particularities of the phenomenon of delocalization and to define the parameters and factors to be taken into consideration in the development of an economic model of the international supply chain in the context of smart delocalization which will improve international trade better.

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Review process

Single-blind peer review process.

doi:10.22306/atec.v7i2.105 *Received: 10 Nov. 2020; Revised: 27 Jan. 2021; Accepted: 09 Feb. 2021*

PREDICTING ON-TIME DELIVERIES IN TRUCKING: A MODEL BASED ON THE WORKING CONDITIONS OF DRIVERS

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Keywords: truck drivers, lead time, arrival time, freight transportation, logistic regression
Abstract: Over a period of two years, 26.3 thousand road freight shipments were recorded. The records include information about truckload companies, drivers, and the causes of non-compliance and delays in deliveries. Logistic regression based in working conditions as independent variables was used to predict non-compliance deliveries attributed to cargo drivers. Results show that vehicle type, medical coverage and social security, level of stress, work dissatisfaction, and transit time were strongly associated with out-of-time-delays in deliveries. The proposed model is a promising tool to improve the performance of truckload companies and it may motivate to benefit working conditions of truckers.

1 Introduction

On-Time Delivery (OTD) is one of the key performance indicators in transportation service companies. Failure to comply with OTDs can lead to breakdowns in supply chains, loss of customers and, in general, high costs for transportation that are assumed both in the short and long term. Consequently, leading companies in the supply chain use data analysis to optimize their operations and prevent disruptions in their processes [1]; however, identifying the causes of deviations and preventing non-compliance in deliveries are an obligated task for companies involved in the transport of goods, since it is a highly competitive market with increasingly narrow profit margins.

In this regard, in the international literature there are studies to predict the arrival time and delays of trucks. Van der Spoel, Amrit, and Van Hillegersberg [2] carried out a review of the literature in which they found 82 investigations related to predictors for arrival time. In this investigation, a classification of the factors found in thirteen categories was made: congestion, weather, speed, distance, type of cargo, type of truck, time of day (week, month, and year), cumulative previous deviation, accidents, road work, traffic signal failures, road condition, and driving style. The authors conclude that congestion, time of day, and accidents are the most frequently mentioned factors and that, in a negative way, they are the ones that most influence travel time. However, it stands out that, despite the relationship with the human factor, no variable refers directly to the working conditions of drivers.

Despite the fact people have a crucial effect in determining a successful supply chain [3], the absence of the working conditions of truck drivers in the prediction models of on-time deliveries appears to be the predominant situation. It is undeniable that drivers are a decisive link in transport chains; and it has been established [4] that some working conditions of drivers lead to emotional exhaustion and, therefore, reduce commitment to the organization, negatively affect the service that drivers provide to the customer and, therefore, cause delays and non-compliance in deliveries on time.

Furthermore, previous studies have indicated that late deliveries are one of the main repercussions of drivers' working conditions in the supply chain [5]. The driving activity subjects workers to risks and demands, derived from the organization and technical division of labour, which implies strenuous work rhythms, intense working hours, market structures and lifestyles that determine the health / illness of drivers and affect their physical and mental health [6,7]. Likewise, these investigations focused on Mexican truck drivers have stated that drivers are in precarious working conditions, do not have social security, are prone to diseases, have high stress levels, are dissatisfied with their work, and are subjected to derived workloads work organization, which include the area where they work, the type of vehicle, the size of the company and the type of relationship they have with it [5-7].

Then, the questioning arises of how the working conditions of the drivers of the freight transport are related in their performance, specifically, in the deliveries on time. In this way, this study aims to explore the relationship between work and drivers' performance, under the assertion that working conditions can explain out-of-time deliveries. Thus, a case study was carried out in a manufacturing company that seeks to reduce non-compliance in deliveries caused by causes attributed to drivers and, based on the availability of variables that determine their working conditions, the binary logistic regression was used to model and predict truckers' on-time deliveries.

Acta Tecnología - International Scientific Journal about Technologies
Volume: 7 2021 Issue: 2 Pages: 47-53 ISSN 2453-675X

2 Methodology

2.1 *Description of variables*

During two years, data of 26,312 shipments were kept track, that of a company which manufactures lightweight construction systems in Mexico. Variables such as the labour relationship (employee or owner-operator), access to social security, age and the results of subjective assessment of stress and the satisfaction of the truck drivers were used to determine the factors that affect the performance in the goods deliveries. The variables considered in the study were determined according to previous studies on working conditions of trucks in Mexico [6,7], and with the availability of information from the company in the case study. Finally, eleven independent variables, which are shown in figures 1 and 2, were considered.

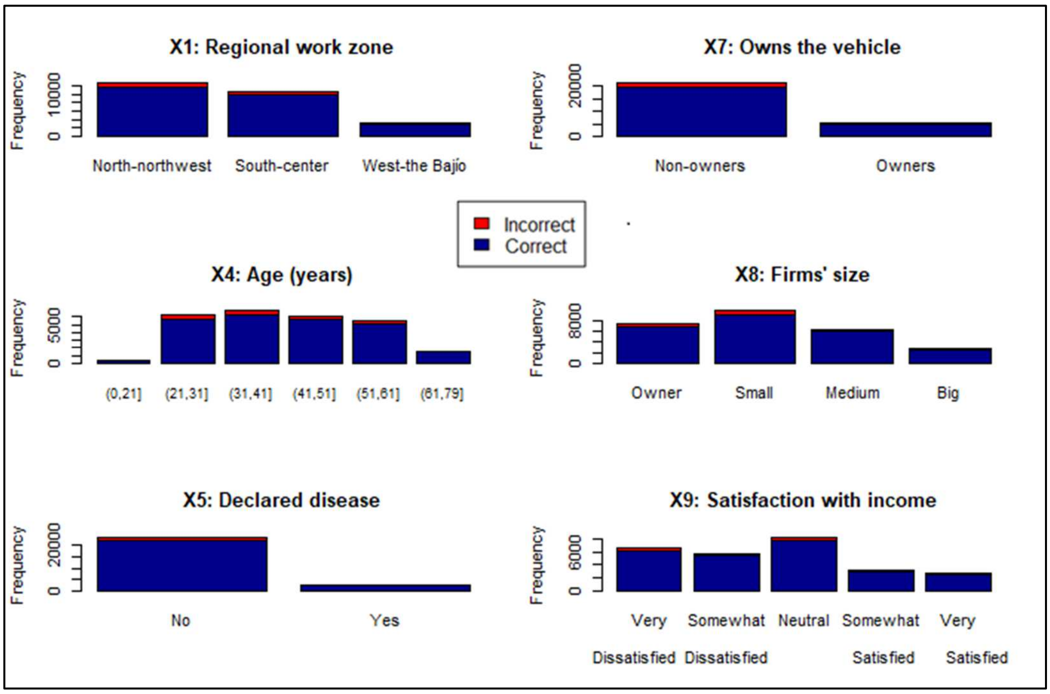

Figure 1 Considered variables that are not in the final equation

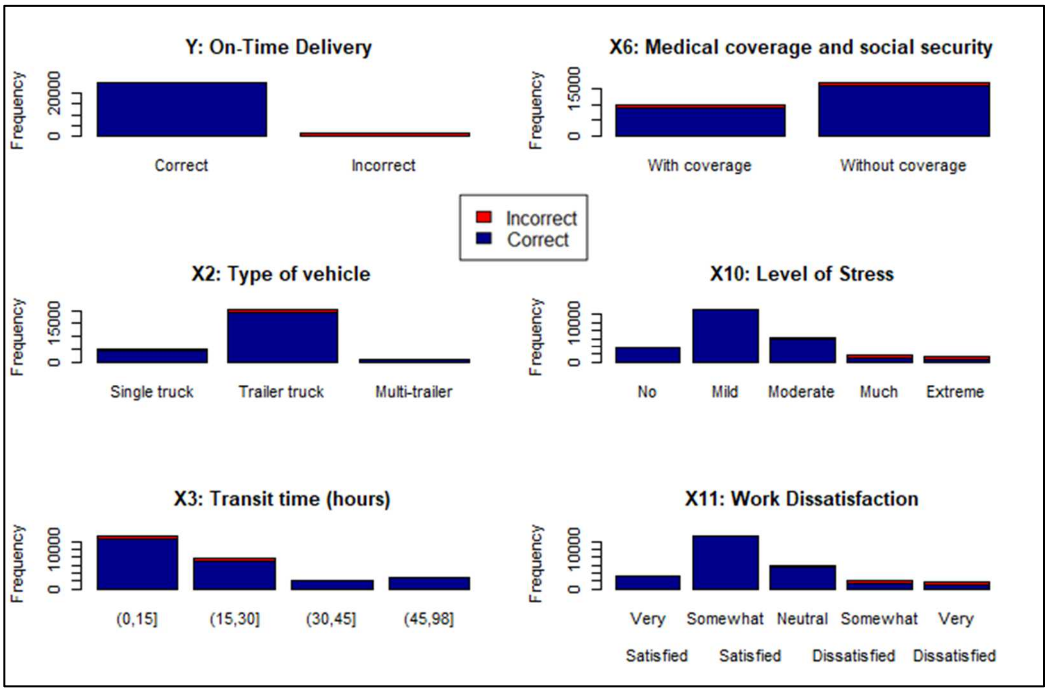

Figure 2 Variables in the equation

After examining the characteristics of the statistical distribution of the variables involved in the analysis, the bivariate and multivariate relationships, and the analysis of the differences between groups the data were tested in several models of multivariate type. Finally, given that the dependent variable, which was named non-compliance of deliveries (Y_{ncd}) has the characteristic of being dichotomous (correct or incorrect delivery) a logistic regression approach was found adequate. In this way, to examine the contribution of the independent variables (figures 1 and 2) logistic regression based in working conditions as independent variables was used to predict on-time deliveries attributed to cargo drivers, its significance was verified, and a model of the parsimonious type was constructed.

2.2 The sending company

The manufacturing company, which produces approximately 80% of the total lightweight construction systems that are marketed in Mexico, makes its shipments in heavy vehicles that are loaded in three plants, located in the north, east and west of the country. The different locations manufacture the same products, with the same quality standards, and are shipped, to be distributed throughout the national territory under the same process in three types of vehicles: single trailer 6-axle truck (77.37%), single unit 3-axle trucks (18.17%) and multi-trailer 9-axle trucks (4.46%), with a capacity of 19, 30 and 56 tons of payload, respectively.

2.3 Truckload Trucking companies

The manufacturing company does not have its own vehicle fleet, so all the transportation of the goods is carried out as an outsourced activity. In total, 52 truck companies were used and were classified by the number and type of vehicles available (company size), the location or work area in which they provide the service (north-northwest, south-centre and west-The Bajío), the access to social security, and vehicle ownership (is or not owner-operator).

2.4 Systematization of data

The information used in this study was obtained through systematic data recording, from a module named Shipment System -programmed and adapted as a complement to a system of Enterprise Resource Planning (ERP)- and whose main objective is creating indicators for transport services, that the sending company subcontracts. The data were divided into three components: shipment tracking, delivery information, and perception of the driver.

The shipment tracking module records the timetable the driver arrives at the loading point and is available to load, the time it is positioned on the loading platform, the start and end time of the loading process, and the departure time in which drivers start the trip to the final destination. In all these processes, several users use different computers and record the schedules by selecting a checkbox, which cannot be manipulated by the users, and where the schedules are captured in real time. These data are compared with the planned schedules and the fulfilment of time of the truck companies and loading dock personnel is verified.

The delivery information is verified through global positioning systems (if the carrier has the service) or telephone reports made by the drivers. Subsequently, they are verified through the delivery documentation (delivery note), in which the client signs the receipt, reports missing or apparent damage to the materials and establishes the date and time at which the carrier arrived, same that is contrasted with the date in which the delivery was promised.

Finally, to assess the perception of the driver, the documents included three mandatory Likert-type questions, with a scale of one to five, which assessed the level of work stress, dissatisfaction at work and satisfaction with income. Other information about drivers, such as the name, age and if he has social security or medical coverage, was previously entered in the drivers register and during the planning of the shipments.

For the logistic regression, R software and GLM function (Fitting Generalized Linear Models) were used, and it was used as a dependent variable and it was coded with a one (Y=1) to shipments that were delivered incorrectly, that is, with damages, out of time, or any cause of non-compliance; and with a zero (Y = 0) for the shipments that were delivered in a timely manner (on-time-delivery). This classification includes only the shipments whose causes of non-compliance were attributed to the carriers, and the derivatives for any other reason, such as programming errors or problems in the loading areas are excluded.

Finally, the logistic regression coefficients were used to elaborate an equation that allows calculating the probability of non-compliance in the timely deliveries of truck drivers. In this way, the categories or values taken by the variables that generate both the lowest and the highest probability of non-compliance were identified and, therefore, can be considered protective or risk factors for fulfilment of on-time deliveries.

3 Result

Of the 26,312 shipments, almost 14% (3,635) were registered as inaccurate deliveries that included any cause and not just transportation issues; that is, they were delivered with some missing, wrong materials, damaged or the promised delivery schedule was not met. Of the non-compliances, 1,790 (6.81%) were attributed to causes related to the carriers; represent the event of interest and were coded with Y=1. The rest of the shipments were considered correct or on-time and were coded with Y=0.

The shipments frequency classified by correct or incorrect delivery is shown in figures 1 and 2. It can be seen that the highest percentage of incorrect deliveries occurs in small (2.6%) and owner-operators (2.4%) firms, in the south-centre area (3.9%) and in the 6-axle truck type vehicle (5.1%). As for trucks drivers, just over a quarter (25.5%) are owners of the vehicle (owner-operator), a fifth (20.6%) have no social benefits or medical coverage, on average they have an age of 40.7 ± 12.99 years, and 8.4% indicated having a permanent disease; mainly of cardiovascular or chronic degenerative type. In addition, it can be seen that drivers who indicated an extreme level of stress got a higher frequency in inaccurate deliveries, whereas this does not seem to be related to drivers who were very dissatisfied with work or very dissatisfied with income.

3.1 Logistic regression and the probability model of non-compliance of

Using R software, the parameters associated to Logistics Regression were calculated. In this way, Omnibus tests of model coefficients showed the probability of obtaining chi-square statistic (7,867.237), so that there is no effect of the independent variables, taken together, on the dependent variable (p<.001).

Meanwhile, the Hosmer-Lemeshow test of the goodness of fit suggested the model is a good fit to the data as p=0.075 and the hypothesis null was not rejected (P>.05). Thus, in general, the model has a high specificity (98.5%) and an average sensitivity (65.6%), so that the model generated through logistic regression offers an overall sample accuracy of 96.3% in the prediction of the event of out-of-time deliveries.

Table 1 provides variables in the equation in the final step; it contains estimated coefficients, standard error, the Wald statistic (z value), statistical significance and the Odds Ratio of the variables involved. Only five variables (figure 2) had statistical significance (P<.05); these are named: Transit time (X_3), Type of vehicle ($X_{2,j}$),), Medical coverage (X_6), Level of stress ($X_{10,j}$), and Work dissatisfaction ($X_{11,j}$), strongly associated with the out-of-time deliveries.

Table 1 Variables in the Equation

Variable $X_{i,j}$	Estimate ($\beta_{i,j}$)	Std. Error	z value	Pr(>|z|)	Exp($\beta_{i,j}$)	95% C.I. for EXP($\beta_{i,j}$) Lower	Upper
βo	-5.42863	0.25954	-20.92	0.00	0.0044	0.0030	0.0070
$X_{2,2}$	0.43417	0.11673	3.72	0.00	1.5437	1.2280	1.9410
$X_{2,3}$	1.18485	0.21412	5.53	0.00	3.2702	2.1490	4.9750
$X_{3,Sc}$	-0.00659	0.00263	-2.51	0.01	0.9934	0.9880	0.9990
$X_{6,Di}$	-0.57919	0.09040	-6.41	0.00	0.5604	0.4690	0.6690
$X_{10,2}$	0.04556	0.25473	0.18	0.86	1.0466	0.6350	1.7240
$X_{10,3}$	1.43868	0.24363	5.91	0.00	4.2151	2.6150	6.7950
$X_{10,4}$	4.88311	0.23592	20.70	0.00	132.0407	83.1550	209.6650
$X_{10,5}$	5.73594	0.23803	24.10	0.00	309.8039	194.3030	493.9630
$X_{11,2}$	-1.44191	0.12298	-11.72	0.00	0.2365	0.1860	0.3010
$X_{11,3}$	0.25132	0.11734	2.14	0.03	1.2857	1.0220	1.6180
$X_{11,4}$	1.72793	0.13054	13.24	0.00	5.6290	4.3580	7.2700
$X_{11,5}$	2.29704	0.13718	16.75	0.00	9.9447	7.6000	13.0120

Otherwise = 0

With the coefficients of regression βi, which were significant, the model is formed to calculate the probability of non-compliance of deliveries (Y_{ncd}) it is presented below (1):

$$\mathrm{P}(Y_{ncd}) = \left[1 + e^{5.42863 - \sum_{i=1}^{n}\sum_{j=1}^{m} x_{i,j}\cdot\beta_{i,j}}\right]^{-1} \tag{1}$$

Table 2 shows the codes for each of its explanatory variables in the final equation. shows the codes for each of its explanatory variables in the final equation.

Table 2 Variables coding

Variable $X_{i,j}$	Variable name	Code
βo	(Intercept)	1: always
$X_{2,2}$	Single unit 3-axel truck	1: present, 0: otherwise
$X_{2,3}$	Trailer 6-axel truck	1: present, 0: otherwise
$X_{3,Sc}$	Transit time (hours)	Continuos
$X_{6,Di}$	Medical coverage and social security	1: present, 0: otherwise
$X_{10,2}$	Mild Stress	1: present, 0: otherwise
$X_{10,3}$	Moderate Stress	1: present, 0: otherwise
$X_{10,4}$	Much Stress	1: present, 0: otherwise
$X_{10,5}$	Extreme Stress	1: present, 0: otherwise
$X_{11,2}$	Work: Somewhat Satisfied	1: present, 0: otherwise
$X_{11,3}$	Work: Neither Satisfied nor Dissatisfied	1: present, 0: otherwise
$X_{11,4}$	Work: Somewhat Dissatisfied	1: present, 0: otherwise
$X_{11,5}$	Work: Very Dissatisfied	1: present, 0: otherwise

Di: Dichotomous variable
Sc: Scale variable

4 Discussion

Some research about drivers has demonstrated that stress affects the performance of workers [4,8]. Thus, it is not surprising that stress has been included as one of the factors in the model and that, to the extent that it increases, the probability of non-compliance of on-time-delivery also increases. However, given that the stress is caused by labour journeys that do not adequately meet the needs of rest, the lack of training to drive their vehicles or other job demands [8]; trying to reduce the level of stress is a complicated task, it already includes practically all the categories of working conditions.

However, it is well-known that an important part of the working conditions of drivers is determined by the characteristics of the vehicle in which they carry out their activities and which has an important influence on their satisfaction [9]. Thus, given that in Mexico 88% of the vehicle fleet is more than twenty years old [10]; delays are evident in terms of ergonomics, comfort, noise, safety and technological devices that facilitate driving; so the old vehicles not only affect the working conditions and the satisfaction of the drivers, but also put in constant disadvantage the competitiveness of the companies.

In addition to the concerns about the characteristics of vehicles, the satisfaction comprises other dimensions such as job demands, organizational issues, work environment, remuneration, the nature of the tasks performed and even personal situations. In this study, satisfaction was evaluated from two perspectives: 1) subjective work dissatisfaction, which evaluates in a general way the feelings and emotions of the drivers (variable $X_{11,j}$); and 2) Satisfaction with income (variable $X_{9,j}$) which assesses wellness or pleasure in relation to the money that drivers receive for their work. However, only the subjective dissatisfaction was included in the model as it was significant ($P<0.01$), and the variable related to satisfaction with income was excluded ($P=0.735$). For these reasons, it is deduced that the drivers are satisfied with their income, although not with other working conditions that are directly related to the inaccuracy of on-time deliveries, so it can be said that the higher levels of work dissatisfaction are related to the risk of out-of-time deliveries.

On the other hand, although the income satisfaction variable was not significant and therefore was not included in the model, it is known that the drivers' income is related to experience and the ability to drive larger vehicles. For example, a driver of vehicles with multi-trailers obtains more income than that of trailer trucks and, in turn, higher income than those of a single unit truck. However, the model shows that vehicles that move more cargo (Multi-trailer 9-axle trucks) are more likely to fail on deliveries.

Other studies indicate that the relative odds of death in road accident increases with the size of the vehicle, and it increases up to 3.42 times for heavier vehicles [11]. Although the model does not delve into accidents, vehicle crashes are considered as non-compliance of deliveries, and the results agree on the risk that the size of vehicles (variable $X_{2,j}$) imposes on the flow of the transport chain. Given that larger vehicles are more efficient in terms of costs and using the different vehicle configurations depends on the planning and specific needs -such as order size or market conditions- it is not feasible, only to use smaller vehicles. Therefore, training and promotion of road safety must be promoted, so that progressively, drivers have new skills that compensate the dimensions of vehicles and reduce risks in the supply chain.

As for work time, although the proposed model does not directly contemplate the workday, days worked per week or resting time; it incorporates within the variables with statistical significance the programmed transit time, which is part of the work time. Transit time is related with to out-of-time deliveries and calculates its highest probability of default (97.18%) in the scheduled deliveries of 36 hours (TOT=36). During that time, a worker drives from the origin to the destination, is present during loading and unloading, he feeds, rests, sleeps and travels about one thousand kilometres. In Mexico, it is common for truck drivers to work by piecework and under a lax regulation of driving hours, which also does not include working hours outside the wheel. Although many hours worked per day can lead bad temper, physical and mental fatigue, excessive drowsiness or anxiety, inattention at work and road fatalities [4], it is known that, a common practice for Mexican drivers is to work up to 76 hours per week and without a proper rest [6]. Consequently, the effects of transit time and long hours of work, not only put the logistics processes at risk through the inaccurate deliveries, but are associated with adverse health effects, such as chronic diseases, or permanent physical and psychological injuries[12].

Also, despite the fact that several studies around the world indicate that driving is among the professions that have the greatest suffering and risk factors associated with their occupation [13], the subjective condition of disease (Variable X_5) did not show statistical significance ($P=0.276$) and was not considered for the final model. While in the opposite way, the medical coverage and social security (Variable X_6) had statistical significance ($P<0.01$) and are considered for the calculation of probability of non-compliance. However, the percentage of drivers who have medical coverage is high compared to the national total of land transit workers, 63.12% for the case study versus 42.09% of the registered drivers in the National Survey of Occupation and Employment [14]. It is important to note that, for this case study, the amount is influenced by the number of companies with more than thirty vehicles, 17.31% against 2.2% in the national total [10]; since, on the contrary of the companies of type owner-operator, greater-sized companies provide these benefits to its employees.

Consequently, having the benefit of social security (X_6), represents that the driver is entitled to several privileges, which include access to health services, vacation, bonuses, pension systems, among others; that guarantee certain compliance in working conditions. Thus, in spite of the fact that in many cases, as a strategy of evasion of labour taxes, the companies register only minimum wage and not the real remuneration of the driver, and so that in case of temporary or definitive disability, or retirement, they only perceive a minimum part of the usual income; the lack of social security is a factor that participates in the calculation of the highest probability of default on deliveries.

Finally, in comparison with other logistic regression models, and despite the fact that they have different objectives, it can be observed that these have some similar variables. Martínez, Oviedo, and Luna [15] to explain the quality of working life, included variables of job stability, physical load, income and some other stressors. It highlights the similarity of the variables related to stress and physical load which are also considered in the proposed model through variables like $X_{11,j}$ and X_3. In addition, in the same way as in the proposed model, neither Martínez et al. [15] nor Villar, Delgado, and Barrilao [16] had a statistical significance for the variable income despite the fact that income correlates positively with subjective work conditions; so you can say that income is not as important as other working conditions for the behaviour of workers. Likewise, Villar et al. [16] did not find statistical significance in the region where employees work but indicates that the autonomy of workers influences their satisfaction. Given that in the inaccurate deliveries model the vehicle ownership variable ($X_{7,j}$) represents work autonomy, it is possible to consider some contradiction between the two studies. However, the comparison study refers to administrative employees, while the current is based on drivers; and the driving activity already implies a certain autonomy in the work.

For that reason, despite the different objectives of this research, the multi-variant analysis with logistic regression models seems to be a good alternative to explain and predict the relationships between working conditions and workers' behaviour.

5 Conclusions

Although the different groups of drivers share risks and demands derived from their labour process, their working conditions vary according to different factors determined by technological, social, cultural, economic and regulatory aspects, including labour laws and traffic regulations; so, some other variables not included in the model could be relevant. However, the five variables used to calculate the probability of non-compliance of deliveries can be considered as dimensions that encompass other factors, and these are related to other working and health conditions, both physical and mental. Thus, for example, the variable $X_{8,j}$ (firms' size) is associated with the longevity of the vehicle fleet, given the larger companies have vehicles with models under six years, while those of the owner-operators are over twenty years.

Briefly, to extrapolate the model to other types of industries, it is necessary to include a greater number of variables (demographic, health, work and organizational, among others), to rule omissions of factors or relevant characteristics, typical of certain industries or products, which may affect the inaccurate deliveries and, therefore, the competitiveness of companies.

In addition, data considered subjective variables. It is recommended that objective methods, as validated tests, are used to measure and reduce the level of stress, job dissatisfaction and the other subjective variables.

However, this study shows the relevance of the working conditions of truckers in terms of how they affect non-compliance in the delivery of goods by road.

The results will be used to create a conceptual model that generalizes, in any type of industry, the effect of labour conditions on inaccurate deliveries. And, finally, despite the limitations of the model, the results show that proposed model is a promising tool to improve the performance of truckload companies and it may motivate to benefit working conditions of cargo drivers.

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Review process

Single-blind peer review process.

doi:10.22306/atec.v7i2.108 *Received: 2 Jun. 2021; Revised: 12 Jun. 2021; Accepted: 27 Jun. 2021*

APPLICATION OF NON-CONTACT PROFILOMETER IN AUTOMATED PRODUCTION

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Keywords: automated line, profilometer, contactless, measurement, automatization
Abstract: The main thesis of this paper was to briefly describe the measurement technique using a non-contact laser profilometer. This paper is divided into several parts, where in the introduction, in the theoretical analysis, we described the necessity of using control mechanisms in automation. Then, in the second chapter, we have developed the technology of measurement with a profilometer and its application in scientific work and in practice. In the experimental part, we have defined the application of a profilometer in laboratory conditions on an automated line in the measurement of a part printed with a 3D printer. Finally, we evaluated the advantages and disadvantages of this device compared to mechanical measuring devices.

1 Introduction

Today, almost all mass production is automated because it is cheaper, more accurate, and requires fewer people. Increasing productivity and the desire to gain a competitive advantage are usually the main reasons many companies initiate an automation project. Other reasons for automation may not be due to "thinking about the future" but rather the presence of current specific reasons - such as a hazardous work environment or high labor costs. Some companies automate processes to reduce production time, increase production flexibility, reduce costs, eliminate human error, or address a labour shortage [1].

Automation solutions usually focus on some or all of these economic and social factors. In this way, the general purpose of production automation can be assigned: to replace human labour and optimize work. In a broader sense, the goals of process automation include [2]:

- Reducing the production of operators.
- Increasing the number of products.
- Expanding the range of products.
- Multiplication of production.
- Increasing production reliability.

Benefits generally attributed to automation include higher production rates and productivity, more efficient use of materials, better product quality, improved safety, shorter workweeks, and shorter lead times. Higher output and higher productivity are two of the most important reasons for using automation. Despite high quality claims from good human workmanship, automated systems typically perform a production process with less variability than human workers, resulting in better control and more consistent product quality. Better process control also means that materials are used more efficiently, resulting in less waste [3].

The use of state-of-the-art measurement and control mechanisms is also a given. One of these technologies is also non-contact measuring systems such as (sensors, profilometers or camera systems). Today these control mechanisms have much more complex functions than in the past. They are used as a control algorithm, as a transformation element between the measured variable and the evaluation unit, or as an element of product quality control in automated production [4].

The principle of these measuring devices is that the measured object enters the measuring zone of the device, the device performs the measurement, and since there is no mechanical contact between the object and the measuring device, high reliability and repeatability of the measures is ensured. Such devices are maintenance-free and do not wear out quickly thanks to the non-contact measurement, which is an excellent advantage for manufacturing companies [5].

2 Principle of non-contact measuring with the profilometer

The profilometer consists of a laser emitter, cylindrically arranged lenses, a light-sensitive receiver lens with a large aperture and a high-resolution CMOS (Complementary Metal-Oxide Semiconductor). The principle of this measuring device is that the laser radiation from the measuring head emits a blue light beam that irradiates the measured surface. The reflected light is projected onto a light-sensitive CMOD sensor and generates a 2D and 3D profile of the measured workpiece, which can then be examined [6].

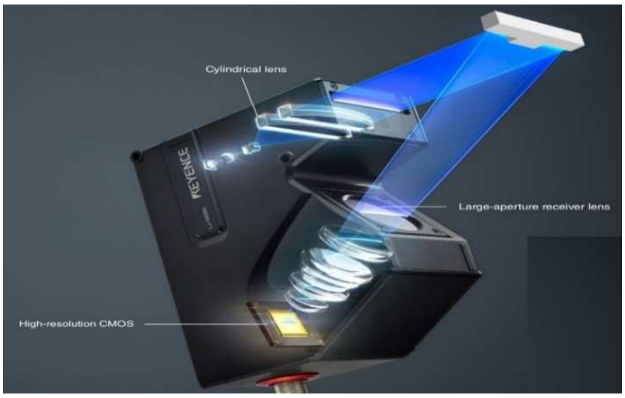

Figure 1 2D/3D Profilometer Keyence [7]

As a measuring instrument, the profilometer is very accurate, as it is supposed to identify and quantify surface elements on a very small scale. Surface roughness is categorized in degrees from "N12" to "N1" according to ISO 4287 and is based on the maximum height difference between microscopic slopes, peaks and valleys to an accuracy of 1 micron [8].

2.1 The state of art

As mentioned earlier, one of the non-contact measurement systems is also a profilometer. A profilometer is a special metrological measuring device that is used to measure the height differences of measuring objects. In technical articles, we can find many examples of the use of this device, such as Leroux et al., whose article focused on the use of a 3D profilometer in the identification of the surface of the paper, where he was able to identify the inscription on the papers printed by laser printer thanks to the ultra-precise microbalance [9]. Mital et al., in their article, use a profilometer for surface roughness identification in waterjet machining [10]. Sun et al., in turn, proposed an algorithm for evaluating the quality (machinability) of the surface texture of tools using a profilometer [11]. Chen et al. came up with the idea of inspecting the surface of gears on clutch wheels using halogen illumination and a CMM-based profilometer [11]. Arezki et al. used accurate profilometer measurements on several ultra-precision measuring machines to evaluate innovative optical aspherical and free-form surfaces [13]. In turn, Oezcan et al. presented an interesting proposal in their work using a camera system and a profilometer to develop a 3D measurement scheme for analyzing the failure of concrete specimens and their porosity [14]. Fiorentini et al. had an even more interesting idea in their study, in which they used a 3D laser profilometer to measure the surface of an asphalt road in order to measure the surface texture of the asphalt exposed to vehicular traffic and environmental erosive influence after each day [15].

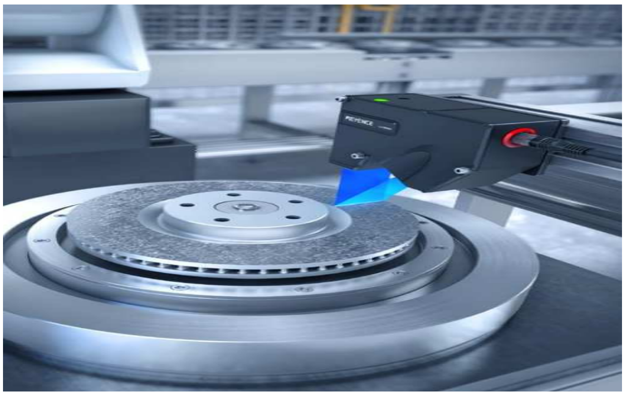

Figure 2 Measurement process with profilometer [7]

3 Application of profilometer in laboratory conditions

The measurement procedure in this article consists of the implementation of a profilometer on an automated line set up under laboratory conditions. The measurement object was a part printed with a 3D printer, which serves as a stabilizing element of the robot arm. The part is made of PLA filament for black 3D printers, which can lead to partial measurement errors for the profilometer caused by the absorption of light by the ink.

Figure 3 shows the measuring head of the LJ-X8400 profilometer from Keyence. This profilometer uses the principle of laser triangulation with a light source, a blue semiconductor laser with a wavelength of 405 nm. The spot size of the laser radiation is approximately 275 mm x 249 µm at a reference distance of 380 mm.

Figure 3 Profilometer Keyence LJ-X 8400

The raw profilometer data is transmitted using a software algorithm that determines the type of element and measures the width of the measured object and the clear distances. The algorithm first uses the difference between adjacent data points to detect a sudden profile change. Sudden changes in surface profile indicate the presence of an element. The object data goes through a second algorithm to classify the object. Data identified as overlap or gap is passed to a third algorithm for width estimation.

Figure 4 Pallet with measured workpiece on automated line

Before the component itself could be measured, a trigger had to be installed on the line, in our case an optical laser sensor. The 48.6 x 48.6 x 7.2 mm workpiece was placed on a prefabricated pallet that served to interrupt the laser beam from the trigger as it moved along the line, informing the profilometer to begin measuring the part. After the pallet passes the sensor, the laser beam is reconnected to the light-sensitive reflective surface, causing the profilometer to complete the measurement.

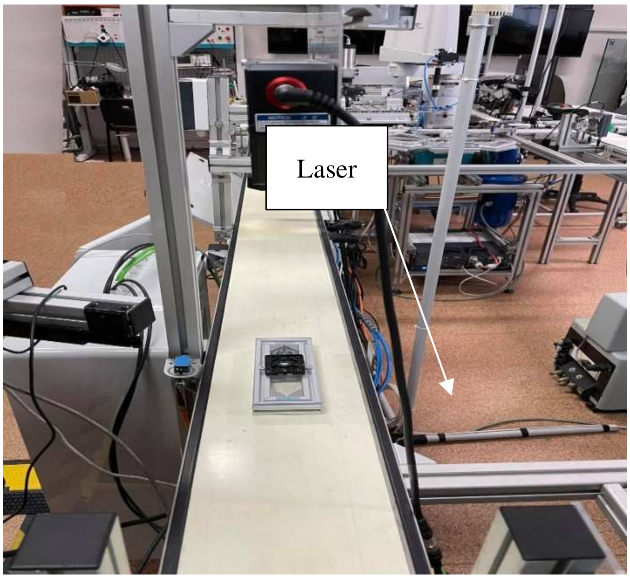

Figure 5 Measurement process of a workpiece with a profilometer on an automated line

After the measurement, the data about the workpiece is sent to the software of the company Keyence LJ-X Terminal Software, where the measured parts are displayed in 3D format. With the help of this software, we can measure height differences of individual components in serial production by determining standard values based on given input height conditions, and the profilometer then measures the difference of these parameters on other components.

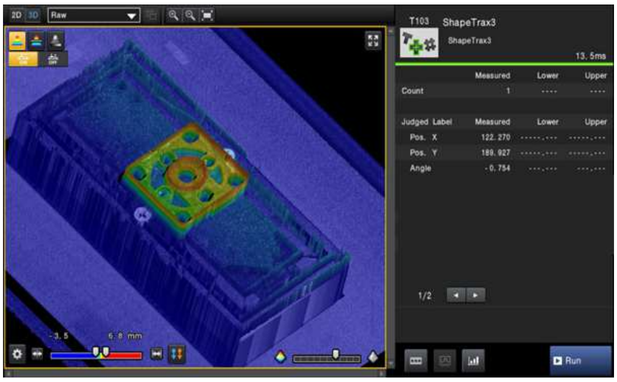

Figure 6 Measured workpiece in the software interface

The zero reference surface for measuring a part is the surface of the pallet on which the part is placed. Figure 6 shows that the software distinguishes the height distribution of the part based on colour differences, with the blue colour representing negative values and the red representing positive values. When identifying defects in production, we can use this device to quickly identify either machining defects or, as in our case, 3D printing defects. The X and Y position data as well as the angle are the reference points for the profilometer for the next measurement. The software also gives us the option of directly measuring the dimensions of individual elements of the workpiece to better identify height differences in the mould.

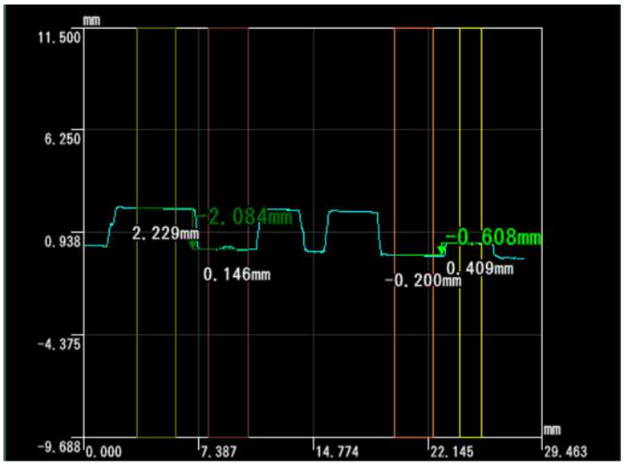

Figure 7 Measurement of height differences on the workpiece

3.1 *Evaluation of profilometer application*

The non-contact gage, instead of a needle used in a light gage, uses an advantage over mechanical gages, namely, the elimination of wear on the contact surface of the gage with the measured component. The advantages and disadvantages of using a non-contact profilometer can be summarized in the following points.

Advantages:

- No damage to the sample surface.
- Ability to measure smaller roughness with high accuracy.
- Fast measurement and high repeatability.
- Simultaneous observation of the surface image and height profile.
- The ability to produce a fully focused, high-resolution image that competes with SEM (3D colour laser microscope images).

Disadvantages:

- The limited size of the measurement target.
- The limited measurement of some surfaces (reflections, colour absorption of light etc.).
- The limited to fixed measurement only in one place (immobility).

4 Conclusion

As we can see, the automation of various production processes increases the speed of the tasks performed. Moreover, in this way, it is possible to eliminate the human factor, the number of frequent errors is significantly reduced, which allows improving the quality of the process. Thanks to the development of new technologies, production automation also contributes to the improvement of control mechanisms, such as the non-contact profilometer LJ-X8400.

As shown in the article, non-contact (laser) profilometers are the best choice for automated production, because thanks to their long-term stability and speed, it is possible to do without technical service for a long time, which is the main criterion for the functionality of the automated line. Furthermore, thanks to the high measurement accuracy and easy-to-use software, the application of this device are very simple. For automated production, this device offers the possibility of quick identification of defects by measuring the profile of the workpiece and then analysing the height differences. In this article, we have evaluated all the advantages and disadvantages of this device and can recommend it without the slightest doubt for the manufacturing sector.

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Review process

Single-blind peer review process.

doi:10.22306/atec.v7i2.109 *Received: 03 June 2021; Revised: 15 June 2021; Accepted: 26 June 2021*

ONLINE AND OFFLINE CONTROL OF COLLABORATIVE ROBOTS USED MIXED REALITY

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Keywords: collaborative robot, ABB Yumi, augmented reality, Hololens 2
Abstract: The presented article points to the combination of mixed reality with advanced robotics and manipulators. It is a current trend and synonymous with the word industry 5.0, where human-machine interaction is an important element. This element is collaborative robots in cooperation with intelligent smart glasses. In the article, we gradually defined the basic elements of the investigated system. We showed how to operate them to control a collaborative robot online and offline using mixed reality. We pointed out the software and hardware side of a specific design. In the practical part, we provided illustrative examples of a robotic workplace, which was displayed using smart glasses Microsoft HoloLens 2. In conclusion, we can say that the current trends in industry 4.0 significantly affect and accelerate activities in manufacturing companies. Therefore, it is necessary to prepare for the arrival of Industry 5.0, which will focus primarily on collaborative robotics.

1 Introduction

Today's trend in technology development is growing at a progressive pace. It is evidenced by the increase in augmented, virtual and mixed reality, namely 23% in industry. Mixed reality (MR) can be on different screens, devices, smart glasses, smartphones, tablets, or even computers. The main element is the camera, which complements the real environment. It is used to improve the perception of the world by integrating various aspects. Displays visualization of the assembly process, video, text instructions and production status update. However, it is also used in multiple fields [1]. For example, industry, automation, education, medicine, logistics, warehousing, aviation. Virtual Reality (VR) - is a technology that simulates a computer-generated environment and gives the user the feeling that he is in that environment. The main tool is headsets, which create a stereoscopic image so that what you see is three-dimensional. They send out completely immersive sounds and sensations to get you to another place where you can communicate with this world. The presence of a person who can move and manipulate objects is simulated. Augmented reality - the main difference from virtual reality is that we see the real world in which artificially created elements are displayed directly into the environment in front of the user. It offers immediate access to information, making it an important application in the industry. This real-world implementation is most often done through smart glasses because they are the most used devices. Of course, it is also functional on ordinary smartphones and tablets [2].

Mixed reality - This reality is one of the innovative solutions to augmented reality. There are three different types. Virtual reality gives you a glimpse into the digital world through a headset. Augmented reality allows you to insert objects into the real world using mobile and other devices. Mixed reality, also called mixed reality, is a step forward, taking it extended to the next level, where we can manipulate images embedded in the real world [3,4]. An example is Microsoft Hololens2, a device that provides us with the real world, but we can integrate with real and virtual objects and create new things or adapt.

In this article, we focus on implementing the already mentioned mixed reality about collaborative robots as companies begin to discover the benefits of collaborative robots. There is more and more talk about operator facilitation, precision, speed and safety. In the eyes of concerns, automated production looks significantly more reliable [5]. The automatic robotic process is more stable, offering more security than the manual process. Robots are part of Industry 4.0. They take over monotonous and hard work from people. Even many robots have an RFID chip in them. They send data to online storage via the Internet of Things as other elements of a smart factory [6]. Such cooperation brings greater flexibility and productivity. All robotic cells must be subject to and meet a safety standard. Over the last 30 years, the average price of robots has halved. Time is running out, and this is reflected in the robots. New safety and construction elements of robots are created, such as speed and torque sensors, round shapes, weight reduction, intuitive movement, soft layers of robots.

With these improvements, development is progressing at a progressive pace. It is assumed that in 2024, a third increase in the integration and sales support of these robots is expected [7].

1.1 Collaborative robots

The first idea to build a collaborative, collaborative robot originated in 1995 as part of the Generals Motors project. From this period, these systems began to be used massively. The advantage of conventional robots is that they work directly with humans. They help with demanding operations, such as screwing in difficult places or handling heavy parts [8]. The aim is to free people from dirty, boring and dangerous work. They are becoming an increasingly common modern attribute, with a gradual reduction in human labour. Robots have great power, so they must comply with the ISO / TS 15066 standard from the point of view of safety. It includes [9]:

1. Manual guidance - After the operator has travelled the critical path, the worker teaches the robot this movement, and it repeats it. When the button is pressed, it switches from automatic mode to manual mode. In automatic mode, it stops when a person enters the robot's path for safety reasons.
2. Safety stop sensor - Protection of safety and health at work comes first. There is a greater risk in processes where there are higher machining temperatures and higher loads. The number of these sensors depends on the type of operation and equipment of the robot. In the event of a stop, the process restarts after pressing the safety button.
3. Speed and distance monitoring - The robots have defined safety zones. If an unknown body approaches an object, the automatic joints slow down until it stops. Robots with this function do not have to be protected by a fence or be in a cage. Unlike the stop sensor, they do not need a physical button press to restart. Safety zones control the operation of the robots.
4. Power and power management- It is a combination of technology monitoring various parameters. All these properties prevent the pressure on a person from exceeding the set limits. These forces and moments are specified by the mentioned standard ISO / TS 15066.

There are already many collaborative robots today. Specialists in the field take care of their installation and programming. It takes several weeks to launch these robots. This cooperation brings greater flexibility and a growing degree of the practical application of the industry concept 4.0 processes [10].

2 Methodology

For our purposes, we used a two-armed ABB Yumi collaborative robot, which is available at SmarTechLab for Industry 4.0 at the Faculty of Manufacturing Technologies, with the seat in Prešov of Technical University of Košice.

2.1 Collaborative robot ABB Yumi

The intelligent ABB Yumi double-arm robot, in short, you and me, offers an innovative ergonomic design focused on people for collaboration. The Yumi was designed mainly for smaller parts and fast handling, thanks to two arms with seven degrees of freedom. It can handle 0.5 kg of payload. Due to its lightweight components, it can work with high speed and accuracy. ABB's growing Yumi robot family is part of exciting collaborative automation solutions that help people work together safely [11].

Figure 1 ABB Yumi

ABB Yumi has found its application in various activities on the market in 5 years. It is a handy solution of 2 arms working independently with seven degrees of freedom, which means 14 axes. It is designed for delicate and sensitive work rather than for small structures with a load capacity of only 0.5 kg. The degree of protection is IP 30. It is recommended to work in a clean environment. Yumi can perform the same tasks around with great accuracy with position repeatability of up to 0.02 mm and a maximum speed of 1.5 m / s.

All types of robots at ABB have their technical parameters. Among the basic specifications of kinematic mechanisms as a whole are technical properties. These include the following technical parameters [12]:

Degrees of freedom - this is the number of independent directions in which the robot's joints can move. It's the flexibility of the robot. Most Abb robots have 6. The unique YuMi, or IRB 1400, has 14 because it contains two arms with seven degrees of freedom.

It reaches the greatest distance that the arm has from its axis or the robot's working space. The range ranges from 500 mm to 4 meters, depending on the work function and size. For example, the YuMi robot does not excel in the long field, but it often catches up over work speed.

Load - this data indicates the maximum load capacity of the robot's end mechanism, with which we can attach, transfer or manipulate the material. The full load depends on the type and size. Devices with a higher load capacity are rather used for handling and palletizing large loads.

Protection - there is a big difference in the environment in which the devices work. Either in a clean environment or extreme conditions. The IP parameter presents this value. Currently, several robots normally meet IP30 / 40, which must be resistant to water, dirt, dust and unwanted dirt, so they meet the requirements of IP67. Painting robots have special IP67 EX protection.

Repeatability - the more accurate the cyclic activity of a given task. It is offered in tenths and hundreds in mm. The influence of acceleration and deceleration provides the term maximum speed. Repeatability numbers range from 0.01 to 0.20 mm.

Usage - ABB has a solution for every industry. So every robot has its spectral use. The better the repeatability of the application, the better the accuracy. Larger robots are usually stronger and more suitable for handling heavy loads. Smaller models are faster, more responsive and unobtrusive. Their main task is to free people from hard work and speed up the production flow.

2.2 Microsoft Hololens 2

Microsoft Hololens 2 is a new vision of work, a new reality in computer technology. It is an updated version of the augmented reality predecessor. Microsoft has worked on some suggestions from users. By enlarging the field of view or by observing the movement of the eyes. A novelty is an eye-tracking function to improve the handling of the hologram. After pressing the holographic button, you can close the instruction sets, start the video or the program. The comfort and convenience of wearing a headset have increased. They make a more convincing impression than their predecessor [13,14].

Hololens 2 is for professionals rather than home entertainment. The target will be companies and various industries with a price tag of $ 3,500. There will also be the possibility of borrowing $ 125 for one user in the company. Such a solution will not burden the company's cash flow. Developers create new offerings—for example, Azure's mixed reality services, such as smart cloud for collaboration. Also, a proven Unity 3D platform with enhanced benefits. Anyone can join a local user group with an open-source project to create mixed reality applications.

Figure 2 Microsoft Hololens2

2.3 Software support RobotStudio

Online manipulation occurs directly at the workplace if the robot is directly connected or in operating mode. There are several types of programming through manual guidance by entering technological, tool and motion coordinates. Another variant is via the Teach pedant unit. It is a device that is used to control a robot. Up to 90% of robots are managed in this way.

A play-back method records the movement by which a person moves with the robot's joint and thus guides the entire technological process manually or copy the path. The last to choose is a text control with commands. Programming is performed in a real environment. It is possible to check for possible errors and prevent potential collisions immediately [15].

Today's trend is more concerned with offline programming in reducing machine times in current automated environments than they say time is money. This technology must be geometrically accurate by comparing the nominal values with the actual state. This type of preparation, imitating the work of a robot, allows you to work without the condition of stopping production, which maximizes the productivity and operation of equipment [16].

The disadvantages include the purchase of additional investments outside the robot to ensure a virtual environment. This program is mentioned RobotStudio, which allows us to create robotic activities offline on the necessary equipment. We can import CAD models and thus configure the required structure.

It determines the positioning of handling points and extreme positions in a measuring system that measures the role of the axes in the joints of the robot. Manufacturing inaccuracies and total deviations of the entire working drive are not taken into account. It is advisable to choose points that are not in extreme positions. Because at the greatest possible stress at the end of its range, the robot tensions the most, and this causes inaccuracy [17].

RobotStudio is a tool for programming, controlling, and simulating all collaborative robots from ABB or ABB Virtual Controller. One of the most used offline programming tools worldwide. With this program, engineers and designers can visualize, deploy, and test the operation of a robot to obtain important data. In RobotStudio, we can place physical surroundings and virtual objects, get as close as possible to reality. It is the same software copy that the robots control directly in production. Production does not have to be interrupted during use. The software contains a model of the control system with all the functions of an entire unit. The basis of all ABB controllers is RobotWare software. The programming language and system modules control the RAPID programming language, which has its commands and functions. In the following section, we focus on configuring Robot Studio with augmented reality. It works on the principle of running RobotStudio, which displays the basic functions of ABB RobotStudio, creating a new solution, adding robots, connecting tools, so-called. Controller either predefined or added using other CAD programs. For our purposes, it is necessary to run the virtual/augmented reality module, define a wireless network to which the collaborative robot and smart glasses are connected [18,19].

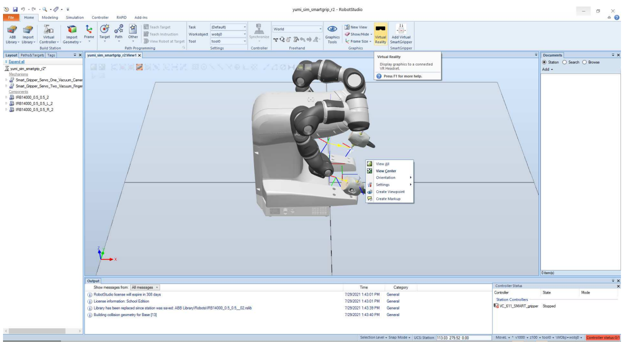

Figure 3 RobotStudio workspace and ABB Yumi location

In this article, we try to show the shift of collaborative technology in cooperation with augmented reality with the help of the RobotStudio Holographic platform and the main program RobotStudio, where we create a schedule, simulate or tune all the movements of the robot. The goal is to teach a collaborative robot to perform tasks using augmented reality. All this through devices that have the necessary compatibility, through which a person sees a robot and at the same time teaches him movements, or after programming, visual and movement control is possible with a virtual display in a real environment. In this way, we can configure the given domain and logistics of the production site. After defining the robot in RobotStudio, we will connect RobotO and Holopraphic to cooperate on the instruction to perform the necessary actions online, and offline from the entered commands. This will create an extended simulation pair working based on the use of augmented reality in real conditions. In Slovakia, economic robotics only in development, however, indicates enormous potential. The latest trend is the use of additive production, where new tools are required that need to optimize the trajectory. The mobile application represents the transmission of a visualization of the robot's course created in the Robot Studio. The commands needed to store and make this data, use the principles, protocols, tools and procedures were defined in RobotStudio and then imported into Robotstudio Holographics. The user can define all parameters.

3 Results

As already mentioned, the first step is to define the type of robot, specifically the collaborative robot ABB Yumi is referred to as IRB 14000. The standard library is referred to as IRB 14000 R - right arm only, IRB 14000 L - left arm only or IRB 14000 with both working arms. We set the selected robot type in RobotStudio. We start the part intended for control transmission, and we pair it with Microsoft Hololens 2 Smart glasses and RobotStudio Holographics application (see figure 4. We used software for live stream transmission of Microsoft Holografic as a tool for 3D view projection.

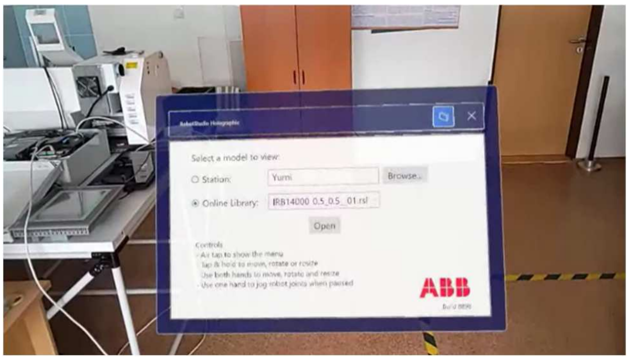

Figure 4 Launch of the ABB Yumi connection to the Holographic environment

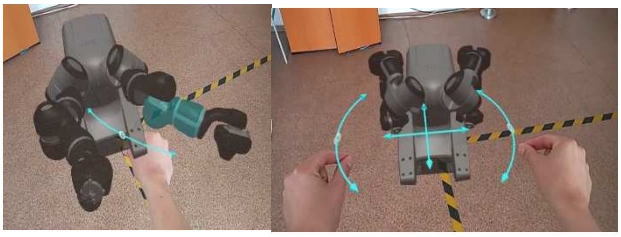

Figure 5 Illustration of ABB Yumi using MR

After pairing with glasses, there will be a real demonstration, a view in space, a holographic view of a 3D model. The object moves dynamically in space. If necessary, we can incorporate it directly into the production line but start it as a whole production process. In combination with ABB, it offers commissioning, where the recorded environment can be applied to the required technological method and navigate the robot to the required position or place. The specification of inputs and outputs is important.

We transferred the 3D model to cover the working field with a real robot in the next part. First, we tested the robot's movements in offline mode, where its task was to repeat the exact actions along a predefined path.

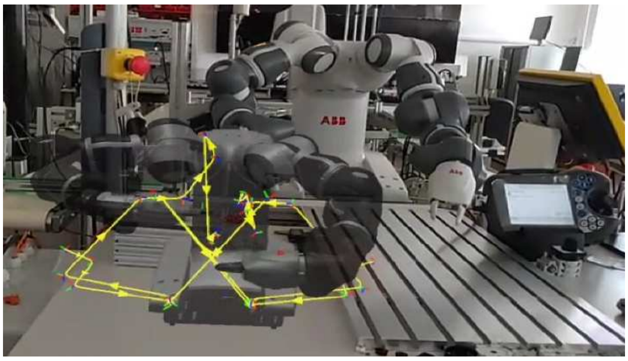

Figure 6 Offline robot test used AR

Following the start of the robot in AR and the definition of motion trajectories, we start copying the motion, and the robot repeats the real movements according to the 3D model. For online motion testing, we covered a real robot and a 3D model. After realising the movement, the robot repeated what we defined for him online with a small delay.

Figure 7 Online robot control in AR

We used ABB YuMi, Microsoft Hololens, Robot Studio and Robot Studio Holographics for the activity. The robot works with 2 grippers, one containing a camera. Control of vacuum grippers for suction and transfer of material to the selected transfer point, using learned hand movements and copying the trajectory of the joint communication of intelligent workstation components with augmented reality. Every movement is recorded and saved. The program records this movement in manual control, holds it in the procedure, and later performs this operation by an automated action.

Figure 8 Real work used collaborative robot ABB Yumi v AR

4 Conclusion

The purpose of this article was to point out the introduction and launch of mixed reality work in combination with robotics for manipulating a collaborative robot. The theoretical part deals with mixed reality, collaborative robotics. In the second part, we described the hardware and software requirements for implementing the experimental feature focused on online and offline control of ABB YuMi using mixed reality. This article points to a new portfolio of applications and technical solutions that can be implemented to date, for example, for educational purposes and for robotics exercises. This type of teaching makes learning interesting, interactive, and modern from the point of view of a new generation of students. The latest trend is RobotStudio Virtual Meeting, which provides a virtual room where participants can connect and monitor information and test the robot's installation in a 3D environment, thus deepening their knowledge in robotics. Mixed reality technology enriches the trainees by 80% more than in comparison with the traditional type of lectures. For education within intelligent technologies in the industry, we can integrate this novelty into exercises or elaboration of assigned tasks. Such a virtual lecture could save a third of the teaching time. As part of corporate training, we can halve teaching times. Mixed reality will support the Just in Time type of logistics to meet time and work requirements.

The aim and design of this article were to point out the use of augmented reality in collaborative robotics using smart glasses and RobotStudio. This simulation model allows us to implement the assigned tasks for performing robot movements on the automatic configuration platform. Specifically, start and transfer control of the robot's movements and speed up its commissioning by simulating the same cell created through the software. We designed the implementation of mixed reality directly with the control of the robot during the use of intelligent devices as a tool for manipulation, programming, and teaching purposes. The challenge was to connect all smart components to ensure compatibility and transfer of digital elements and their storage in the cloud and RobotStudio. The exact procedure and spectral use are described in the design part as the realization of mixed reality, together with real examples. This article proves that technology is advancing at an incredible pace, and we can take it with us. This means anywhere and anytime. We can control a robotic workplace. New trends such as mixed reality accelerate production processes and bring many benefits that are part of Industry 4.0 and the upcoming Industry 5.0.

Acknowledgement
This work was supported by the Slovak Research and Development Agency under the contract No. APVV-19-0590, by the projects VEGA 1/0700/20, KEGA 055TUKE-4/2020 granted by the Ministry of Education, Science, Research and Sport of the Slovak Republic and by the

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Review process

Single-blind peer review process.

Acta Tecnología - International Scientific Journal about Technologies
Volume: 7 2021 Issue: 2 Pages: 67-70 ISSN 2453-675X

doi:10.22306/atec.v7i2.110 *Received: 04 June 2021; Revised: 19 June 2021; Accepted: 28 June 2021*

APPLICATION OF VIRTUAL REALITY IN THE DESIGN OF PRODUCTION SYSTEMS AND TEACHING

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Keywords: Virtual reality - VR, design of manufacturing systems, Siemens Tecnomatix, AutoCAD, Simio
Abstract: The content of the contribution is a description of the virtual reality use in the design of production processes and in the teaching process. The aim of the article is to describe the methodology for 3D virtual design of production systems as well as a description of the creation of interconnectors for simulation tools Siemens Tecnomatix, Simio, AutoCAD and Dassalut systems by using the moreViz tool. The use in the design of production systems lies precisely in the ability to realize the projected space on a scale of 1:1, which will allow maximum use of space and its orientation. The effect in teaching lies in a better understanding of the elements that can be displayed in fully immersive virtual reality, which helps to teach faster and engage spatial imagination.

1 Introduction

The exponential growth of technology in the world is getting to the point where expensive technologies have become conventional in the past [1]. Virtual reality is one such technology. Virtual reality is already commonly used in many sectors such as design, medicine, education, design [2]. Simulation is beginning to play an important role in the design of manufacturing and logistics systems [3]. The art of creating simulation models depends not only on defined scheduling rules but also on the spatial imagination of the designer [4]. However, in some cases, it is impossible to estimate the exact size of objects and distances as the design takes place on a scaled-down scale. Virtual reality currently appears to be the most helpful here. The potential of virtual reality is enormous and may represent a pre-jumper for hologram technologies that are currently the subject of many researches, such as Brigham young university [5] or Kyungpook National University [6]. The use of virtual reality devices allows us to create arbitrarily large objects that the human brain interprets as 3D. With appropriate programs, the commonly used CAD software work environment necessary for designing production systems can be converted to a virtual model that is on a 1:1 scale display device. In its content, the post describes the methodology for the virtual 3D design of production lines as well as the description of the creation of a virtual bridge between Siemens Tecnomatix, AutoCAD, Dassalut systems and SIMIO tools using the moreViz tool for design as well as teaching.

2 Methodology

The virtual 3D design methodology consists of 7 modules. These are modules that represent the whole process of system design, including model verification and validation as well as optimization. Figure 1 Displays the methodology for the virtual 3D design of production systems.

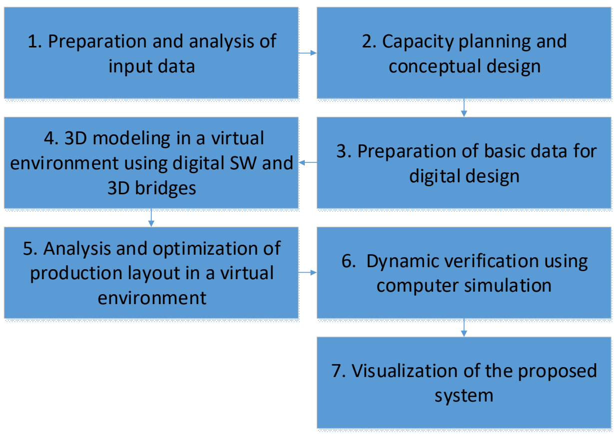

Figure 1 Methodology for virtual 3D design of production lines and creation of interconnectors bridges

1. An important aspect of any design activity is the collection of data, which are subsequently analysed. This data serves as an input into the model, if the data and its scope are correct, the simulation model is valid with a real system or with a planned idea. On such models, it is then possible to conduct simulation experiments to gain consequences for the modelled system.
2. The next step is to determine the required requirements for outputs, on the basis of which the capacities on the machines, their number, resource requirements, operation, etc. are determined. This step is realized when it comes to designing a new production system.
3. At this point, the data obtained necessary for real system modelling shall be compiled, where appropriate, in the new design of the number of sources and equipment and other data obtained from the capacity requirements plan and conceptual design.
4. If we have data collected, modelling of an optimized production system or a proposed new system can be realized. Gradually, all entities that represent real elements in the production system are added. In this module, it is convenient to use the input to fully immersive virtual reality, where we can get a visual and spatial idea of the modelled system and model correctness. At the end of the modelling activity, verification and appropriate, validation are carried out.
5. If the simulation model is designed correctly, its parts may be optimised, as the logical correctness of the model guarantees an effect when applied to the real system. Here it is possible to use the cooperation of various workers from different departments, who use the bridge to fully immersive virtual reality to get a better visual idea. With their comments, they finalise the simulation model to meet the targets and to suit stakeholders in future production.
6. The simulation model created shall be verified using appropriate computing power. If the model is verified, we can say that it is logically correct and the information from such a system has a telling value.
7. In the last module, the simulation model is ready for use in practice for visualization needs and ideas about the behaviour of the future system and for the needs of conducting experiments that can bring real benefits to the system. In this module, it is also possible to enter virtual reality and get a visual and spatial idea of the future system.

3 Results and discussion

3.1 Creation of connecting bridges for Oculus Rift S - Siemens Tecnomatix, AutoCAD or Dassalut systems

First of all, it is necessary to have installed one of the software (Siemens Tecnomatix, AutoCAD, Dassalut systems). Then it is necessary to download moreVIZ software, which in the next process will serve as the creator of a 3D virtual model based on the model that we want to virtualize for glasses. SteamVR software is then downloaded. It will serve as under the application on which the created 3D virtual model will run. The above example is for working in Oculus Rift S virtual reality glasses. After installing this software, the video card driver is updated, which is a very important step, otherwise, you will not be able to connect between the PC and the eyewear hardware. If all files are installed, we can go to the software setting up. MoreVIZ Server Control is set up first so that the software correctly connects the desired program. The setting shows Figure 2.

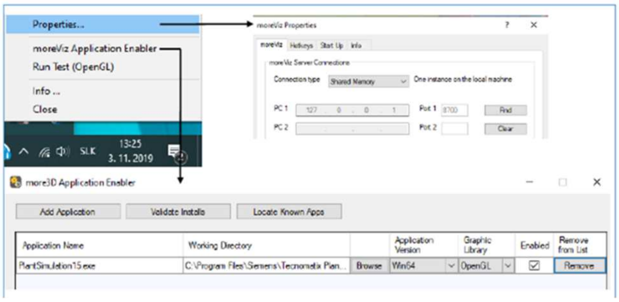

Figure 2 Setting moreViz Server Control

After this step, the moreViz Client is running, where the type of goggle link is set (the program also allows you to link to the Cave display method). The setting shows Figure 3.

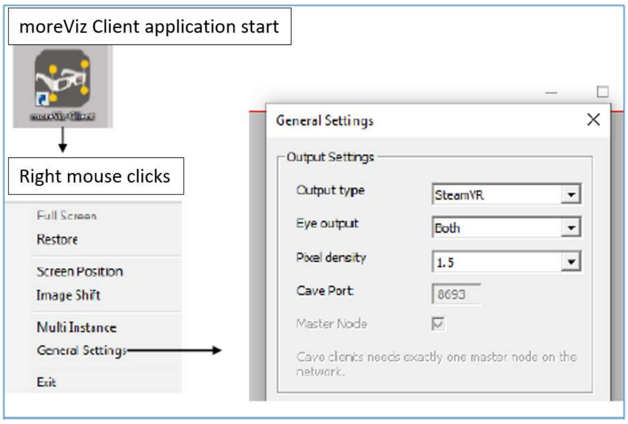

Figure 3 Setting up of moreViz Client

After this step, we close both moreViz Client and Server Control and run Tecnomatix Plant Simulation or other software and set the values in the settings as shown by Figure 4. The OpenGL 1.5 (Vertex buffer objects) value must be set.

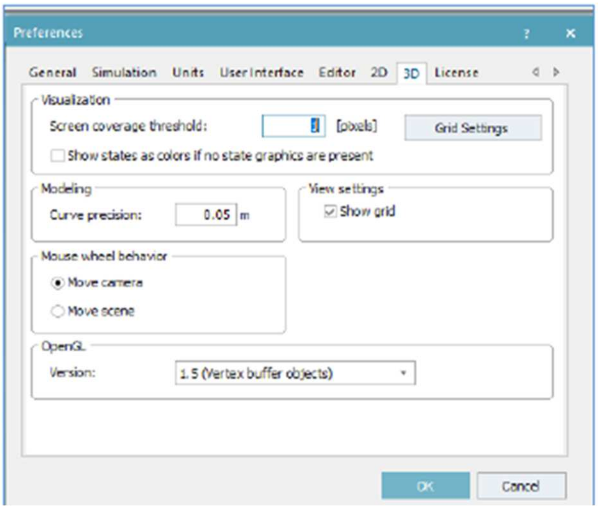

Figure 4 Working software Tecnomatix Plant Simulation set up

We can then proceed to work in software and connect to fully immersive virtual reality. Programs must be run in order as shown in Figure 5.

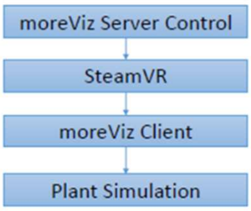

Figure 5 Link step sequence

After running Oculus Rift S glasses, we turn on desktop sharing with your PC. In this environment, we can work on a simulation model, change elements, add them, run simulations, and more. Such a work environment depicts Figures 6 and 7.

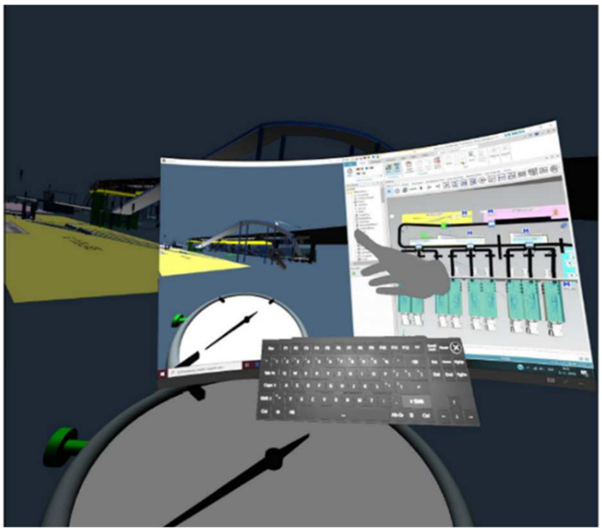

Figure 6 Example of Oculus Rift S virtual working environment in goggles

Figure 7 Example of defining parameters in a virtual work environment

After adjusting the parameters and running the simulation, we can enter fully immersive virtual reality by switching to the launch of SteamVR Figure 8. This will get us into a mode where any movement is possible in the fully immersive virtual reality of the Figure 9 simulation model.

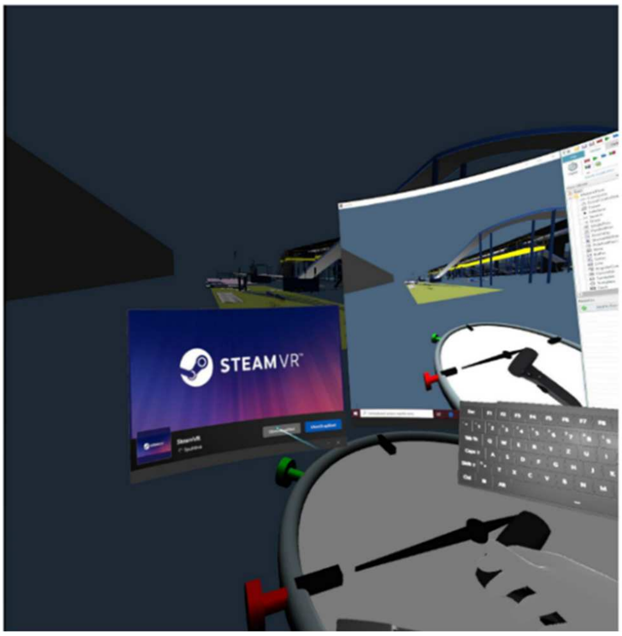

Figure 8 Example of moving to fully immersive virtual reality

3.2 Creation of a connecting bridge for SIMIO

Creating a bridge between this software and glasses is much easier than in the case of other software. SIMIO has a built-in Oculus Rift S link function in the Project Home – Render to Oculus bar. After its launch and deployment of HMD Oculus Rift is displayed a fully immersive virtual reality model, where movement is realized by the letters ASDW.

The established methodology in which the connecting bridge is applied realized through moreViz software helps both with the design production systems themselves and in the teaching process. What is one of the most important tasks in designing is detailed design. In this process, the final layout of the elements, together with their demands for space in a common 2D and 3D view, plays a rather complex matter. The ability to realistically observe on a real scale embedded models of objects in the location of their place facilitates this process. On the one hand, it is possible to verify whether the utility distribution in space as well as to compare the ergonomic suitability of the layout. In the field of education, students who learn in the field of industrial engineering have a facilitated process of memorization of knowledge when learning different types of logistics or manufacturing systems thanks to the experience on dynamic simulation models of these processes.

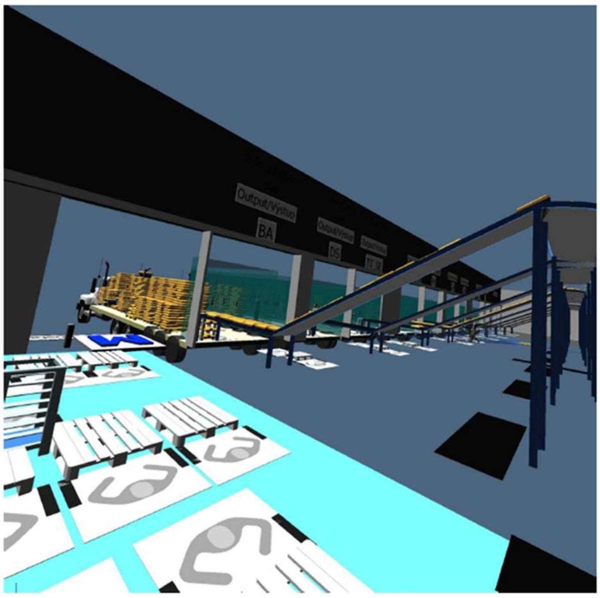

Figure 9 Example of movement in simulation model

4 Conclusions

Advanced industrial engineering can be understood as a constant application of the latest knowledge and technologies into practice. The use of virtual reality glasses significantly improves the work of designers as well as production system designers. The use of glasses allows a better understanding of the spatial vision of the projected system. Models can be entered and seen on a scale of 1:1, which helps to optimally place elements in the system as well as improve the security of the projected system. With the perspective of teaching, the virtual reality application of glasses will help students better understand the inserted elements, this helps to faster teaching and engage the spatial imagination of students.

Acknowledgement

The paper is a part of project VEGA No. 1/0225/21 „Competence manufacturing islands for Factories of Future – new approach to planning, control and optimization (CMI-FoF)“.

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Review process

Single-blind peer review process.

JOURNAL STATEMENT

Journal name:	**Acta Tecnología**
Abbreviated key title:	Acta Tecnol
Journal title initials:	AT
Journal doi:	10.22306/atec
ISSN:	2453-675X
Start year:	2015
The first publishing:	October 2015
Issue publishing:	Quarterly
Publishing form:	On-line electronic publishing
Availability of articles:	Open Access Journal
Journal license:	CC BY-NC
Publication ethics:	COPE, ELSEVIER Publishing Ethics
Plagiarism check:	Worldwide originality control system
Peer review process:	Single-blind review at least two reviewers
Language:	English
Journal e-mail:	**info@actatecnologia.eu**

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Phone:	+421 948 366 110
Publisher e-mail:	**info@4sgo.eu**

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