Simulation Model of an Ultra-Light Overhead Conveyor System; Analysis of the Process in the Warehouse

Batin Latif Aylak, Bernd Noche, M. Baran Cantepe, Aydin Karakaya

***Abstract*—**Ultra-light overhead conveyor systems are rope-based conveying systems with individually driven vehicles. The vehicles can move automatically on the rope and this can be realized by energy and signals. The ultra-light overhead conveyor systems always must be integrated with a logistical process by finding a best way for a cheaper material flow in order to guarantee precise and fast workflows. This paper analyzes the process of an ultra-light overhead conveyor system using necessary assumptions. The analysis consists of three scenarios. These scenarios are based on raising the vehicle speeds with equal increments at each case. The correlation between the vehicle speed and system throughput is investigated. A discrete-event simulation model of an ultra-light overhead conveyor system is constructed using DOSIMIS-3 software to implement three scenarios. According to simulation results; the optimal scenario, hence the optimal vehicle speed, is found out among three scenarios. This simulation model demonstrates the effect of increased speed on the system throughput.

***Keywords*—**Logistics, material flow, simulation, ultra-light overhead conveyor.

I. Introduction

OVERHEAD conveyors play out their benefits precisely when demands to the currently available conveyor technology become more complicated and trickier. Overhead conveyor is an extremely efficient way of transport with great diversity for designing the internal goods traffic effectively. They are used for transporting, saving, buffering and providing goods and products with floor-free, innovative conveyor. Due to their modular structures, these conveyors allow application in a wide range of areas [2]. Overhead conveyor systems become particularly suitable as demands to the conveyor systems rise [5]. This way, speed, high availability, high loading capacities and high position accuracy can be achieved. Due to its control system travelling with it, the system offers an optimal material flow and a highest degree of flexibility for a great variety of applications. Each vehicle of overhead conveyor is equipped with a control system travelling with it, which conveys in a suitable way with the central control system. The control commands are relocated and controlled on board in chassis functions, such as driving, stopping, speed regulation, lifting or commissioning and discharge of transport goods respectively [5]. A permanent or variable coding of drives allows the alignment and administration of driving orders as well as carrying along of process data for the purpose of material flow control.

Ultra-light overhead conveyor systems are much more flexible than ordinary monorail conveyors and can practically follow any path to adapt to any transport plan. Its bolt construction enables a lot of configuration possibilities.

Simulation has been defined as the imitation of the real-world process or system over time. Simulation tools are specifically designed to limit transient effects on measurements, which can be used in estimating a set of efficiency measures in production systems, inventory systems, manufacturing processes, materials handling and logistics operations [4].

In addition, experts notice that in use of electric monorail conveyor systems, companies often have considerable maintenance and system update costs. Therefore, companies should also consider the long-time costs and consequences of the integration of an overhead conveyor system in their work process.

II. Model Explanation

This model is about the analysis of the warehouse. The warehouse serves from Monday to Friday, from 8:00 am to 4:00 pm. Packages have to be transported between several departments in the warehouse. This is about an ultra-light overhead conveyor system. The vehicle hangs in two parallel running ropes, which are running underneath one another, and proceeds with a self energy supply on the ropes. The vehicle transports payload with the robotic gripper, and the vehicle and the robotic gripper are connected with a leverage. The vehicle supplies four loading and unloading stations. The stations are being operated by the robotic gripper. This model is supposed to clarify the following question:

Is it possible to increase the throughput by increasing the vehicle speed?

In the following Table I a list of definitions is shown about this model.

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TABLE I
GLOSSARY ABOUT THE DESIGNATIONS USED IN THIS MODEL

Designation	Definition
Model, simulation	Both of them are about the same realization, the assessment of the operating numbers of the warehouse
Package	Packages which are transported among several stations
Warehouse	This is a warehouse of the post centre
Model, simulation model	This describes the simulation model of the warehouse in the simulation tool DOSIMIS-3

III. MODEL SIMULATION

Following assumptions were made in this model:

- There are two roller tracks in every station. One roller track is used as loading station. The other roller track is used as unloading station.
- The length of the package is 0.5 meters.
- The standard loading and unloading time is 7 seconds.
- The quantity of packages depends on the stations.
- Every 100th second there is a new package in every station.
- The flow of material is only acceptable into one direction with this model
- The duration of the executing simulation was set to 480 minutes

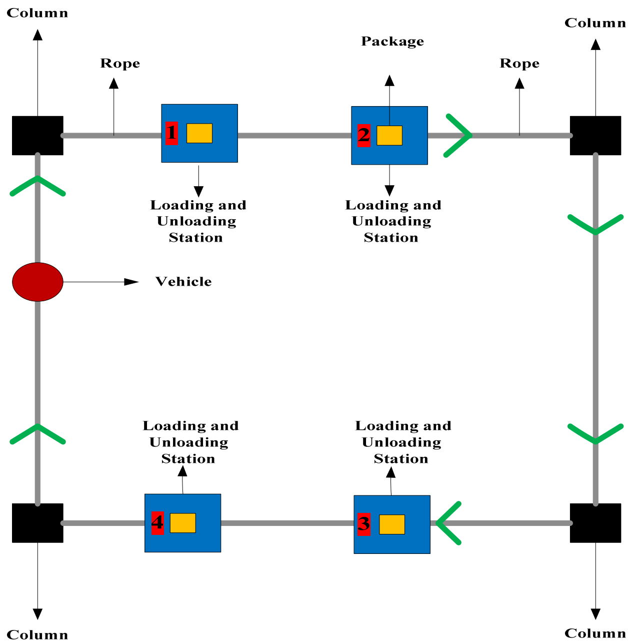

Fig. 1 Layout of the warehouse

Fig. 1 represents the layout of the warehouse. Each station has one unloading station and one loading station. Distance between the loading and unloading station at every station is assumed to be 0.5 meters. Moreover, the green arrows show the material flow direction.

As soon as a package arrives in the station it is considered as being system related. After this point, the package is in the statistics of the measured indicators of the simulation.

TABLE II
SIMULATION TOOLS OF THE WAREHOUSE SIMULATION

Number	Type	Name	Parameter
24, 28, 38, 47	Source	Entry	Time assumed:=(fixed, cycle time:=100s)
33,36,42,50	Accumulation Conveyor	Roller track	Segment length:=1m, conveying speed:=1m/s, number of segments:=10
34, 35, 43, 49	Accumulation Conveyor	Roller track	Segment length:=1m, conveying speed:=1m/s, number of segments:=10
18, 26, 37, 46	Loading Station	Package counter	Length:=1m, object length:=0,5m, holding point:=1m, speed:=1m/s, standard loading time:=7s, strategy: FIFO, fixed, cycle time:=10s
19, 25, 44, 53	Unloading Station	Package delivery	Length:=1m, object length:=0,5m, holding point:=1m, speed:=1m/s, standard unloading time:=7s, fixed, cycle time:=20s
27, 30, 40, 48	Track	Trip between two roller tracks	Length=1m, speed:=1m/s
51, 52	Track	Trip between two stations	Length:=4m, speed:=1m/s
20,23	Track	Trip between two sides	Length:=15m, speed:=1m/s
22, 31, 41, 45	Sink	Exit	Time assumed:=(fixed, cycled time:=1s)

Table II represents the construction of the model as it is used in this simulation**.** Tracks represent the vehicle in the model. Parameter of track speeds will be different at every scenario. For example, track speed is assumed to be 1m/s in Table II. That means, Table II shows the parameters of first scenario, where the vehicle speed is 1m/s. Various components are numerated in Table II and their parameterization is explained. These parameters were overtaken from the researches and assumptions. The parameters which are not mentioned here have the standard values of the DOSIMIS-3 application. Those settings are accepted as initial values, which are used in order to answer the question from the model explanation part.

DOSIMIS-3 is a simulation tool specialized to answer questions related to functionality and performance measures of a logistics system and widely deployed in industry as well as logistics education and training in German-speaking countries. DOSIMIS-3 provides an extensive library of components from the material-flow and logistics world, enabling model-building by a few clicks on the basis of a well-structured conceptual model [1].

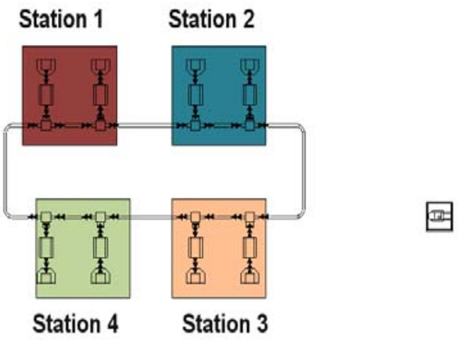

Fig. 2 Simulation model in design edition

Fig. 2 illustrates how the model looks in simulation mode. The packages are waiting for transportation and at the same time, one package is being transported.

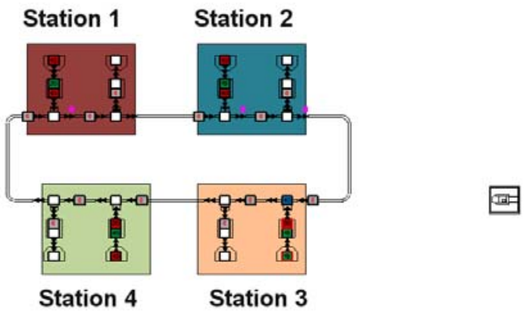

Fig. 3 Simulation model in active mode

Fig. 3 shows how the model looks in active mode. The model of the system is being simulated through.

It has been shown that the value measurements of the source cannot be based on the algorithms which are implemented standard with DOSIMIS-3. But DOSIMIS-3 offers the opportunity to implement a separate distribution. For this reason a file needs to be created which describes the generation of the packages.

In reality packages do not continuously arrive in the warehouse. In DOSIMIS-3 distributions, which are determined by the number of the packages and a specific period of time or by the priority of a package, are possible. The number of the packages can be set as a whole and capacity can be set as well.

In this case, object generation takes place in random order.

IV. Results

This chapter describes the simulation results. It has shown how the current system works; therefore the vehicle speed plays an important role in increasing the efficiency of the warehouse.

Simulations were run without any errors and the final results are identical to the results of the test run process.

Three different vehicle speeds were tested for the investigation about the throughput of the packages.

The following definitions contain measurements about the simulation. Those measurements correspond to the following definitions:

- Throughput: The throughput describes the number of packages which are being transported in intervals.
- Middle occupation: the middle occupation is the average amount of the occupation number of the simulation process.
- Percent occupation: The percent occupation describes the average percent occupation.
- Utilization: The utilization is a percent value of the utilization about a simulation step.
- Blocking times: number of the seconds in which the module can´t work; because congestion had been caused in the following elements or the contemporary module is working.

First of all, three different speeds were selected for the vehicle speed. Then, these speeds were raised with equal increments at each scenario. Later on, the simulations were executed for three different speeds. Finally, the throughput analysis is shown for each loading station. Scenarios were based on the vehicle speed with equal increments. First vehicle speed is selected according to the real-life overhead conveyor system application.

Tables III-VI represent output analysis of the loading stations according to vehicle speeds.

TABLE III
OUTPUT ANALYSIS OF LOADING STATION-1

Speed of the vehicle (m/s)	Throughput (# of package)	Utilization (%)	Percent Occupation (%)
1 m/s	380	5.42	4.1
1.1 m/s	403	5.50	4.22
1.2 m/s	425	5.62	4.39

TABLE IV
OUTPUT ANALYSIS OF LOADING STATION-2

Speed of the vehicle (m/s)	Throughput (# of package)	Utilization (%)	Percent Occupation (%)
1 m/s	379	5.38	4.06
1.1 m/s	403	5.50	4.22
1.2 m/s	425	5.58	4.35

TABLE V
OUTPUT ANALYSIS OF LOADING STATION-3

Speed of the vehicle (m/s)	Throughput (# of package)	Utilization (%)	Percent Occupation (%)
1 m/s	379	5.38	4.06
1.1 m/s	403	5.50	4.22
1.2 m/s	424	5.58	4.35

TABLE VI
OUTPUT ANALYSIS OF LOADING STATION-4

Speed of the vehicle (m/s)	Throughput (# of package)	Utilization (%)	Percent Occupation (%)
1 m/s	379	5.38	4.06
1.1 m/s	403	5.46	4.19
1.2 m/s	424	5.58	4.35

Figs. 4-7 show throughput analysis of the loading stations according to three different speeds.

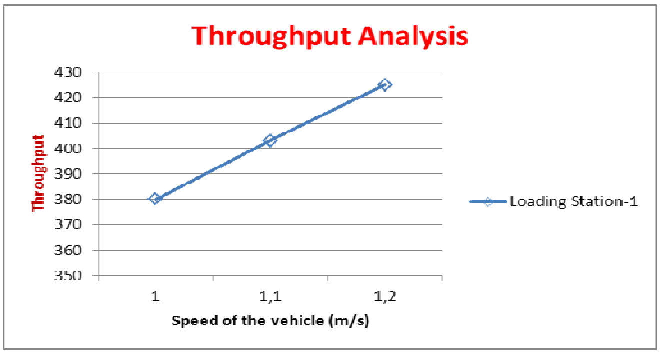

Fig. 4 Throughput analysis of the loading station-1 according to 3 different speeds

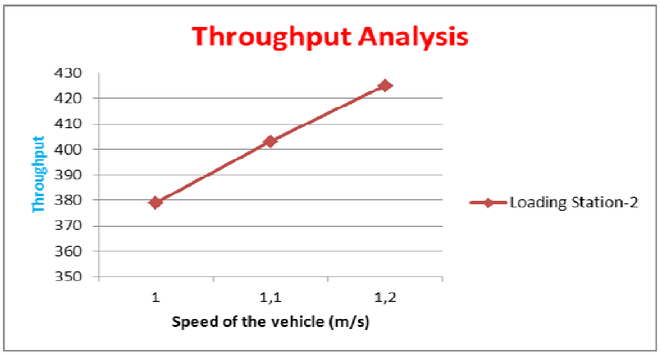

Fig. 5 Throughput analysis of the loading station-2 according to 3 different speeds

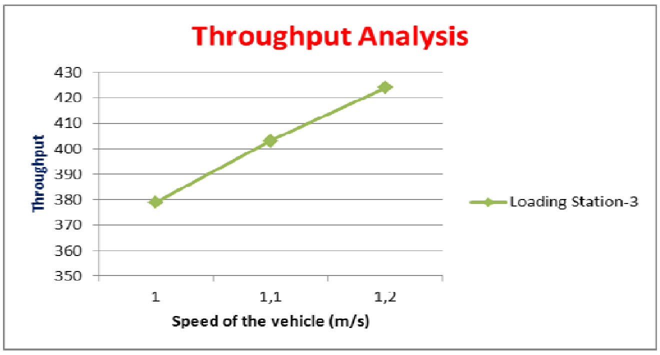

Fig. 6 Throughput analysis of the loading station-3 according to 3 different speeds

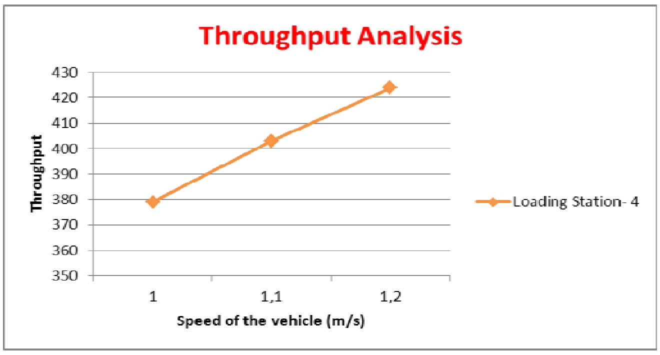

Fig. 7 Throughput analysis of the loading station-4 according to 3 different speeds

According to throughput analysis, system throughput will be increased in case of raising the vehicle speed with equal increments. Necessary technical analysis must be made in order to find out maximal vehicle speed in the system. So, the vehicle speed plays a major role on the system throughput.

With the help of the research, it was tried to create a model which is close to reality [3]. Thus it was pointed out that the vehicle speed plays a huge role in the increase of the throughput. All those results only indicate a very possible solution, however there will never be a simulation model created, that coincides a 100 percent with reality. In that case the whole system would need to be predictable.

As an advice, it can be said that the current system of the warehouse could be yet optimized. One recommendation would be to increase the vehicle speed to 1.2m/s. By this means the throughput is increased. If the vehicle speed exceeds 1.2m/s, the vehicle would face stability issues when cornering. Therefore, this problem should always be considered.

V. Conclusion

This paper aims to investigate the correlation between the vehicle speed and the system throughput, and also to find out the optimal vehicle speed among three selected values. This paper gives an overview about the real life scenario.

Simulation analysis and its results enable a comprehensive demonstration of the processes or abstract ideas and provide a better understanding on these processes or ideas.

According to the simulation results, the optimal vehicle speed is found as 1.2m/s where the maximal throughput is reached.

This research consists of assumptions from the real life case. There are numerous applications of overhead conveyor systems. But most of these applications are designed for heavier loads. There are also some overhead conveyor systems, which are designed for lighter loads. Technical specifications of these overhead conveyor systems are taken into account when the simulation model was built.

There is not any industrial application of rope-based ultra-light overhead conveyors at the moment. Despite of the lack of research, the approximate simulation results are represented in the throughput analysis. In the future, a real-world application of a small scaled ultra-light overhead conveyor system will be built up, and the real optimal vehicle speed will be determined according to this application.

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