Handling Dynamics in Logistics - Adoption of Dynamic Behaviour and Reduction of Dynamic Effects

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Abstract

In this paper, the performance of production networks by employment of autonomous control versus those with conventional material planning under a dynamic business environment is investigated. Regarding this, by developing a discrete-event simulation model of an exemplary production network the competency of application of autonomous processes (in bearing flexibility) is presented. A new treatment approach of dynamics in logistics is represented by depicting a short spectrum of approaches. Behaving as a dynamic system against fluctuating demand is the one side of this spectrum and reacting as a constant system with conventionally planned material flow is the other side of that.

***Keywords**: Production, dynamic and autonomy*

1 Introduction

By emerging the phenomenon of global competition in the market, one can not neglect the importance of customer fulfilment at the right time, place, quantity, and quality. Realisation of this task is challenged by several aspects of existing dynamics in business environments. On the one hand steady increasing requirements and expectations of customers [1], and, on the other hand, scarce resources and the corresponding competition can be considered as some dynamics' causes. A transparent example of the dynamics is the changing market and demand volatility, as external causes. In addition, shifting bottlenecks, changing in routings and production strategies are some effects as internal logistics.

To cope with such a rapidly changing environment and to promptly react to the dynamics, enterprises have been applying several strategies, which tend to decrease the undesirable effects of dynamics. They employ some neutralizing methodologies or corrective actions due to drop changes in-time plus on-time adaption to them, e.g. adaptive manufacturing systems.

With regard to the mentioned disturbances, conventional production planning and control -or in a wider scope material planning and control- methods are not well suited to react to the unpredictable and rising changes, by forecasting situations anymore [2]. To solve this problem various chronological systems have been presented. The most recent one called autonomy is a promising paradigm. It is introduced to improve handling of the existing dynamic complexities within a production system [3, 4]. Here, autonomy means autonomous control in material routing and flow, i.e. "a decentralized coordination of intelligent logistic objects and the routing through a logistic system by the intelligent objects themselves" [5]. In previous works it has been proved that autonomous control methods boost the ability and the performance of logistics systems in better handling the dynamics in demands [5,6]. However, in this paper, two approaches are introduced to cope with dynamics; reduction of dynamic effects (which could be considered as damping activities) and adoption of dynamics behaviour, which could be used for amplifying the required flexibility of a logistics system encountering dynamic changes. Both approaches synergise with each other to achieve the targets of handling and reducing dynamics.

Conventional strategies could be considered as those which are accommodated with predefined plan based on the general availability of resources and capacity. Normally, the conventional systems seek to eliminate or reduce undesirable dynamic effects. In contrast to the conventional logistic strategies with counteractive activities against sudden changes, a new approach to handle the existing dynamics is introduced in this paper. In fact, by applying the advantages of autonomy, it is tried to express this approach as adoption of dynamic behaviour in order to react in real-time to tackle budding changes, like a dynamic system.

The past studies on autonomous systems showed the capability of this paradigm in tackling dynamic effects in virtual world, i.e., dynamics have two aspects. One of the aspects is the causes and the other one is the effects of the dynamics. However, if material planning and control methods' spectrum has an extreme side with a hierarchical and pre-determined plan that is inflexible against changes, the other side of that is an extreme decentralized and fully autonomous system with several hard to realize specifications and requirements. Actually, both conventional and autonomous strategies have some pros and cons, i.e., on the one hand the conventional one is easy to realize but inflexible to cope with dynamics, on the other hand autonomous strategy is hard to realize but competent to deal with the changes autonomously [3]. Hence, in this level of development a combinatorial approach of them seems to be favourable and practical.

Based on this context, a combination of these two conventional and autonomous strategies is explored in the current study. For this purpose some explanations for the both systems are given which is followed by a short introduction of production networks. Furthermore, a discrete-event simulation model of a production network scenario is developed to analyse the causes and effects of micro-dynamics inside the supply chain's elements, and macro-dynamics throughout the entire network. At the end a summary and outlook will be given. It is noticeable that the motivation of this study is to donate more practical aspects to the autonomy paradigm and make it more compatible with the state of the art to handle dynamics in logistics.

2 Conventional vs. Autonomous systems

Application of conventional material handling and production planning & control (PPC) systems was suitable for those predictable business environments with quasi-constant demand. By presenting new markets and global competition a positive loop has been appeared that increases the requirements of customers respectively the producers. Today, introduction of new planning and control systems is considered necessary.

Since conventional material handling and PPC systems seem to be incapable to satisfy stochastic demand, several improved systems have been introduced in a chronological order to enhance the performances. Scholz-Reiter et al. have briefly compared the most popular ones of them, including the Flexible Manufacturing System, the Reconfigurable Manufacturing System, the Holonic System, and the Autonomous Manufacturing System [3].

Initially, flexibility in a production system was considered as reducing set-up time and rapid changeovers [7]. This characteristic has been taken into account by some initiatives systems. For example, the Lean Manufacturing System could comply with that specification which for several years has shown its capability in existing production systems. Thereby, its competitive advantages rather are proved in a relatively constant demand with moderated product variety [8]. Nevertheless, lean manufacturing mostly aims to cut any kind of activities which causes some instability into the robust system. Concerning that, lean can be considered as a conventional system in some degrees with levelled production schedule, i.e. lean manufacturing against mass production with fully conventional system, faces with some difficulties when the demand is stochastic and fluctuating [7,8]. In general, the lean concept follows a trade-off between producer and customer to get a quasi-constant level of production pace in the logistics system to eliminate any non-value added activities. Despite this, lean principles also cover some methodologies to confront with instabilities plus adoption of flexibility which are used by its successive systems like the Agile Manufacturing System.

It is noticeable that the Flexible Manufacturing System originated the agility concept. After the initial perceptions, later the flexible manufacturing has extended its business context, thus the agility concept has been appeared. Agility has been introduced in order to deal with volatile demand and changing business circumstances [7,9]. It is believed that by introduction of the autonomous control system, as a flexibility tool, a new door is opened to the agile manufacturing concept.

Responsiveness is the utmost goal of an agile system [9] while autonomous system has demonstrated its contribution to the throughput time, respectively lead time [4, 5], [10, 11] as responsiveness criteria [7, 12]. Autonomy in logistic processes by adoption of dynamic behaviour actively contributes to improve responsiveness of the corresponding system.

According to the collaborative research centre 637 "Autonomous cooperating Logistic Processes: A Paradigm Shift and its Limitations", the following is a wide definition of autonomous control as part of autonomous systems. "Autonomous control describes processes of decentralised decision-making in heterarchical structures. It presumes interacting elements in non-deterministic systems, which possess the capability and possibility to render decisions independently. The objective of autonomous control is the achievement of increased robustness and positive emergence of the total system due to distributed and flexible coping with dynamics and complexity." [13]. According to this definition autonomous control is characterised by a shift of decision-making capabilities form the total system to its elements, which allows intelligent logistic objects to route themselves through a logistic network according to their own objectives [14]. The term intelligent logistic object is broad defined. It covers physical objects (e.g. parts, machines, etc.), as well as immaterial objects (e.g. production orders). Due to novel information and communication technologies, these objects are able to interact with each other and to gather information about current local system states. These intelligent logistic objects are able to generate decisions according to their own logistic targets on the basis of this information. This kind of decentralised decision-making may influence the systems behaviour positively and may help to improve the handling of dynamics, for example occurrence of unforeseen events (e.g. machine breakdowns) [15]. In the context of production logistics first approaches of autonomous control have been developed and modelled. These models showed that autonomous control may improve the performance of production systems and confirmed that autonomous control increases the ability to cope with changing dynamic effects [6,11].

As far as production networks are concerned, autonomous control also showed promising results. First investigation of a production network showed that autonomous control may harmonise the production output of the entire network for fluctuating demands [16].

In this paper, briefly, conventional material handling and flow systems are those with an objective of even production pace with levelled and sequenced flow. This is regarded as counteraction to the dynamic effects inside the logistics systems.

Here, it is going to exhibit the capability of the autonomy paradigm to enhance the performance of the agility concept. Furthermore, by a coalition of a conventional strategy with an autonomous one –as adoption of dynamism- the existing dynamics inside a production network scenario will be tackled. This cooperative idea is based on the Leagility concept and positioning of decoupling point [7,12]. However, even flow in upstream of the network and oscillating one in downstream is the result of the strategy.

3 Production networks

Production networks are configured by cooperation of interrelated companies aiming at integrated planning and correlative value added processes, whilst the companies' facilities are geographically dispersed [17, 18]. Production networks concentrate on the incorporated planning and control of material and information flow. Integration of geographically distributed decisions and planning, company spanning processes, as well as resources and material allocation are the core tasks of production networks. Thus, new approaches dealing with the complexity and dynamic of production networks are necessary [19, 20]. These accompanied challenges with a production network make it suitable for evaluating the performance of autonomous systems.

According to this context, the structure of production networks propagates the complexities embedded in every single plant -as internal disturbances- to the entire network. In a network, the importance of members' integration and the significance of coordinated information flow and material planning and control, make it much more complicated for being properly regulated than in a single shop floor [21]. Indeed, due to heterogeneous desires of network's members (e.g. a successive plant requires semi-finished products in a specific pallet and quantity which is not easy to deliver) along the required flexibility and interdependencies of PPC for such a network, competitive administration of the network is quite challenging to get realised. Material and resources allocation beside transportation capacity and planning are other examples of the mentioned complexities [22].

The next part presents a simulation model of a production network scenario to analyse the performance of autonomous control in cooperation with conventional strategies, in confronting the fluctuations in demand and material flow. It explores the local and global behaviours of the combined strategy.

4 The network scenario

Regarding the definition of production networks, an exemplary network is considered for the experiments. The network in macro-view consists of a j×k production plants matrix in addition to an upstream plant as well as a downstream original equipment manufacturer (OEM). The network is partitioned in j stages that k production plants are embedded in each. In the micro-view every plant represents a shop-floor with m production stages -with a predecessor buffer in front of each- and n parallel production lines. The plants are connected via a transportation system (Figure 1).

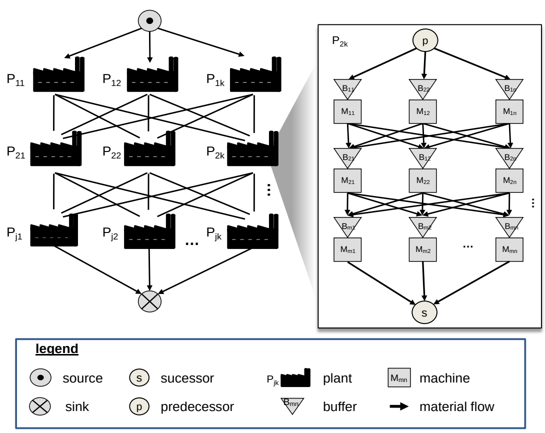

Figure 1: Production network with j×k plants

To fulfil the objective of handling the fluctuating demand, as a factor of dynamics inside logistics, the respective simulation model is developed with several practical constraints and presumptions. These are representing the damping factor in conventional strategies to moderate the effects of fluctuating demand and reduction of bullwhip effect proliferation.

After being processed in a plant the semi-finished products are buffered in an exit inventory -using the First in First out (FIFO) method- until a transportation order is released. The practical means of transportation in the scenario are trucks with a maximum capacity of 6 parts and a speed of 70 km/h. Every transportation order is regularly released with an interval of 4 hours, i.e. transport interval (TI). Every time a truck carries 4 to 6 products depends on the upstream load of the network. It is noticeable that the considered capacities for every element in the scenario are examined before to fulfil smoothly the average load of the raw materials in the upstream source.

Now, the discrete-event simulation model is developed to analyse the current scenario. To reduce complexity of the assumed network, the model is reduced to six production plants which are collected in four stages. For inside of each plant a (3×3) matrix of workstations is considered (e.g., see Figure 1).

As mentioned, a plant is located on the entrance of the network in stage one and an OEM is the only plant for leaving the network on stage four. On stage two and three there are two parallel plants with the same characteristics and operating abilities. To show the geographical distances of plants, they are uniformly distributed, i.e. between a plant and its successor there is a two way road with 140 km length (Table 1).

Table 1: Distance matrix of plants inside network

	Distance [km]					
Plant	**P_{11}**	**P_{21}**	**P_{22}**	**P_{31}**	**P_{32}**	**P_{41}**
P_{11}	---	140	140	∞	∞	∞
P_{21}	140	---	∞	140	140	∞
P_{22}	140	∞	---	140	140	∞
P_{31}	∞	140	140	---	∞	140
P_{32}	∞	140	140	∞	---	140
P_{41}	∞	∞	∞	140	140	---

According to the velocity of the trucks, it takes 2 hours for a truck to drive to another plant. Thus, every delivery interval takes 8 hours at all. It should be mentioned that the materials just meet every plant once, and on the return way the truck is empty. Material flow starts from the source plant at stage one and have to pass all other stages to terminate at stage four.

There are three types of products or jobs (Type 1, Type 2 and Type 3) with different processing times at each production line on the shop floor level. Table 2 shows the different processing times for each product type on every production line of every plant

Table 2: Distance matrix of plants inside network

Plant	**Processing times [H:MIN] per plant**					
	P_{11}; P_{41}			**P_{21}; P_{22}; P_{31}; P_{32}**		
Type	1	2	3	1	2	3
Type 1	2:00	3:00	2:30	4:00	5:00	4:30
Type 2	2:30	2:00	3:00	4:30	4:00	5:00
Type 3	3:00	2:30	2:00	5:00	4:30	4:00

Here, a unique push - pull strategy for the assumed network is considered to produce and deliver products. By setting a decoupling point [8] at the entrance of the last plant, upstream from this point follows a push principle, whereas downstream from that (OEM) has a special pull principle, which is a conwip (constant work in process) production system [23].

For this network strategy, two types of demand for evaluating and analysing the performance of conventional material control and autonomous are arranged. These are both examined and the results of them are shown in the following sections.

4.1 *Fluctuating load*

To model seasonal demands a fluctuating material load with a sinusoidal function (1) is set as follows:

$$\lambda(t) = \lambda_m + \alpha \cdot \sin(t + \varphi) \qquad (1)$$

Equation (1) represents the occurring rate of both load and demand. Each product type loads in the first plant by a phase shift of 1/3 ×φ respectively 2/3 of a period. The mean arrival rate is set to λ_m = 0.4 with amplitude of α = 0.15. Due to this arrival rate in average every 2:30 h a new part of every type enters the production network. Figure 2 presents the corresponding inter arrival times of the sinusoidal arrival rate (1) for all three product types. It shows that furthermore that the period of the sine function is normalised to time period of 30 day. According to this the maximal and minimal inter-arrival times of each product type is reached once in this 30 day period.

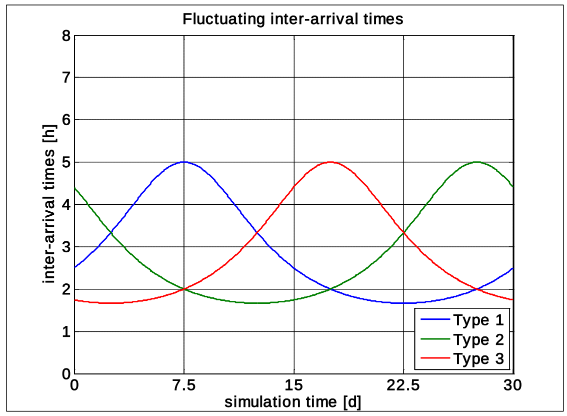

Figure 2: Inter-arrival times according to sinusoidal load function

The time horizon here is considered as 240 days. This sinusoidal load represents a seasonal effect in demand respectively dynamic effects. The intensity of these seasonal fluctuations is determined by the amplitu d e α of the sin e function (see [1 1] for more information).

4.2 *Constant load*

Two different constant loads at the upstream of the production network are considered to present the role of decoupling point (D.C) in splitting up the production network into two pull and push strategies. Within this loading strategy the smooth push flow in the upstream is represented.

A loading interval with 2:30 h, as the mean value of sinusoidal demand, and also a loading interval with 3:00 h are supposed to show a predictable demand and constant production pace in the upstream network from D.C.

4.3 *Assumed conwip system*

However, for simulating the pull strategy in an agile system the last plant has a continuous sinusoidal demand at all. To do so, it is handled by a conwip system.

To simulate the conwip system each product should be moved by a pallet. In the last plant there are three types of pallets that just carry their respective products in lot-size of one. For each demand order from a customer a stored pallet will be released to the entrance of the shop floor to represent its availability and appeal for the related product. The finished pallets will be stored again in their buffers and will wait for the next order. At any time an order is released and no related pallet is available in its buffer a record list registers a backlog. Even if a product is waiting for a pallet at the entrance buffer this waiting time is recorded as the local throughput time for that product and prolongs the makespan. This is not entirely comparable with real world backlogs of manufacturers but shows a delay in customer fulfilment.

It is noticeable that all flows are one piece flow even on the last plant. This was taken because of its significant contribution to continuous flow of material by offering less lead time and more flexibility [24]. The upstream from D.C can follow the lean principles, while downstream of that should be agile [12].

5 Planning and control strategies

For benchmarking a conventional planning (CP) versus an autonomous control system the following structures are pursued: a centralised planning method with predetermined routing control is considered as CP. In this strategy the jobs on a shop floor are assigned according to the stations with shortest processing times for the corresponding product type.

Between the recognised autonomous control methods in previous studies, here for easier comparison the Queue Length Estimator (QLE) method is selected as autonomy representative. The QLE method is based on the comparison of the buffer levels of each production station and selection of a successor station with the least cycle time and buffer level. In other words, the parts (as intelligent logistics objects) use this method by collecting the real-time and local information about the successors (buffers and stations) to choose the least waiting route, respectively the shortest throughput time (see [11] for further description).

In the macro aspect of the network, those parts, which have finished their processing operations in P_{11}, P_{21} and P_{22}, have two possible successive plants for proceeding (Table 1), which in this model they are sent in an alternative order.

In order to depict the influence of two controlling strategies (CP and QLE) on agility and lean production systems, respectively push-pull, two indicators are underlined for comparison. Throughput time (TPT) as a factor of responsiveness in agile manufacturing and working percentage of stations or, in the other words, utilisation as a factor of value added activity are the reasonable metrics for the current study. The both metrics are indicators of a logistic system performance and could be considered as business excellence metrics.

6 Simulation and results

To depict the effects of demand fluctuation, as a dynamic factor, there is considered a continuous sinusoidal demand in the form of a pull strategy just in the last plant (OEM) after D.C point. The other five plants before the D.C have always the same strategy with push load. It is noticeable that, here, the assumed loading scenarios are considered to evaluate the both concepts of damping and amplifying the dynamics effects and causes.

For example, fluctuating loads could be the cause of fluctuating TPTs, besides having amplifying rolls to the fluctuations. On the other hand, the corresponding material flow strategy could deal with those dynamic effects and have a damping roll for more tiny fluctuations.

To do so, following, the three types of loading scenarios at the upstream plants are evaluated through two different types of flowing strategies, i.e. conventional and QLE.

6.1 Upstream fluctuating load

With sinusoidal loads as push flow at the first source plant the following results are rendered. Figure 3 exhibits the comparison graph of global (entire) throughput times between CP and QLE methods for the network. To better distinguish the results just the last 500 products are displayed in the following graphs that have a time horizon of 55 days.

As shown here, the performance of QLE is better than CP, in terms of TPT as our expectation. At the overall time horizon the mean TPT of QLE method is

66:42 hours with just 1:48 hour standard deviation (STD), whereas mean TPT for CP is equal to 74:07 hours with 4:23 hours STD. This shows the compatibility of QLE method with production networks. Especially the standard deviation of TPT for the QLE method shows that this method leads in this case to fewer variations in the production output.

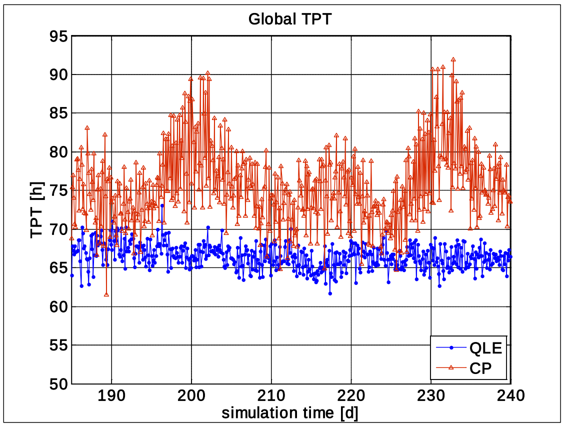

Figure 3: Global TPT of QLE vs. CP in the network

Figure 4 shows the TPT of QLE versus CP just in the last plant (OEM) with pull sinusoidal release of pallets for carrying products as pull demand.

Nevertheless, the performance of QLE against CP in the last plant is quite considerable. QLE performance is getting a bit worse than CP in the OEM by comparing mean TPT and STD values.

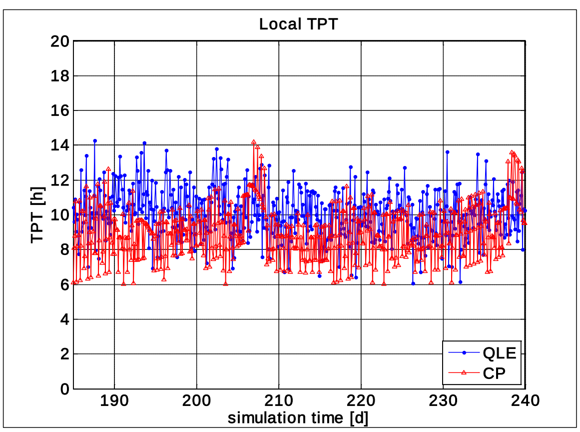

Figure 4: TPT of QLE vs. CP in P_{41}, sinusoidal load

This could be explained by the sinusoidal pull demand of this plant, pallet availability, sequence of the loads, and the different phase between push load and pull demand. The other points are abrupt entrance of the semi-products with a lot-size of 8 to 10 as well as a constant 8 hours interval for each delivery. However, it does not represent any weakness of QLE method but it proves the importance of integration in information flow and coordination between plants' activities. Even D.C point dose not solve the problem of distinct operations here.

Table 3 shows a clear view for the two strategies by comparing the mean and STD values of the all six plants. Here, the superiority of QLE before the D.C point under fluctuating loads is underlined.

Table 3: Mean and STD of all network plants

	CP		QLE	
	Mean	**STD**	**Mean**	**STD**
P_{11}	9:40	4:16	7:08	0:59
P_{21}	17:54	5:26	15:28	2:16
P_{22}	17:02	4:20	15:20	2:14
P_{31}	20:09	7:16	15:53	1:47
P_{32}	17:47	5:35	15:26	2:20
P_{41}	8:48	2:16	10:26	2:27

Additionally Table 3 shows that there is a bigger difference between the mean values of the parallel plants, compared to the QLE. This explains the standard deviation of TPT of the global network. Additionally to this the STD of remaining plants is at least twice bigger compared to the QLE method. In contrast to this the differences of mean TPT for the QLE method are lower between the different plants. This implies that the QLE method smoothens out the TPT of this network in this case.

Although the TPT of the QLE method after D.C point is worse than CP, but the other indicator of business excellence, e.g., utilisation of resources is better in QLE than CP. Figure 5 displays the working percentage of each station in P_{41} with two CP and QLE strategies.

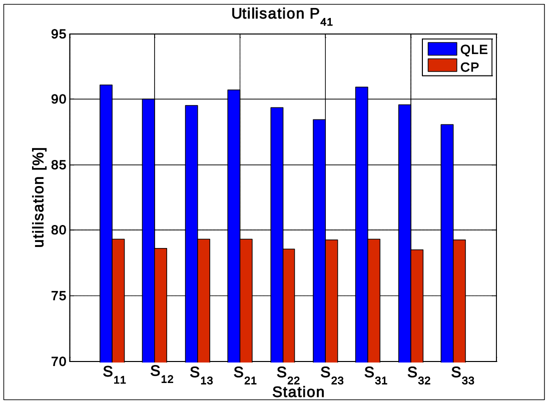

Figure 5: Working percentage of each station in P_{41}

The other excellence factor as customer service level is the level of backlogs. Obviously, the more backlogs enterprises collect the less service level they have. In this case the collecting backlogs (as the average of three types of products) are 31.67 products for CP and 24.67 products for QLE method.

6.2 Upstream constant load

Here, a discharging scenario with a constant load for every type of the three products is considered. The load strategy is considered to expose the performance of the both QLE and CP confronting with two controversial aspects of load and demand (constant load and sine demand).

An interval of 2:30 hours between each load of each product (50 min between one type to the other type of product) is set up for this experiment. The interval value is extracted from the mean value of the sinusoidal load rate. This loading strategy represents a constant demand in the upstream from the D.C point, which is subject to conventional planning and control systems.

In fact, in this case scenario, the performance of QLE and CP is almost the same in upstream from D.C as expected. This is because of the responsive cycle times of stations for the average load of 2:30 hours. Nevertheless, the performance of QLE (again in the case) is a bit worse than CP at the last plant (OEM). The cause of this unforeseen phenomenon is the sudden delivered (by transporters) bulk of lot-size, the sequence of loads versus demand orders, and the pallet availability on time. This means in addition to route changes other disturbances here are influencing as dynamic factors, that the important ones are pallet availability and impulsive replenishments.

It is very important to know that, in general, if we exclude the waiting time of products in the entrance buffer of OEM for getting carried by the corresponding pallets, the performance of internal routings of the autonomous control (QLE) is still better that the CP, according to our experiments results. Nonetheless, here, we decide to integrate this idle time, in the entrance buffer, to the local TPT in order to show the necessity of compatibility for autonomous control event in critical points of a production network. Figure 6 displays the comparison graph of the global TPT between CP and QLE methods in this scenario.

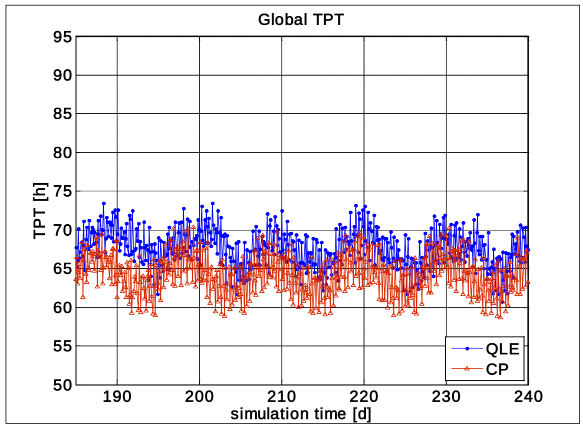

Figure 6: Global TPT of QLE vs. CP in the network

The mean global TPT for the all products in QLE is 67:36 hours with STD of 2:20 hours, whereas for CP mean value of global TPT is 64:08 with 2:23. For local values in the OEM, the QLE has a TPT of 13:24 hours with 2:06 hours STD and CP has a TPT of 9:56 hours with STD of 1:57 hours.

Figure 7 illustrates the performance of methods in P_{41} (OEM) with a sinusoidal pull demand. Here again, according to the sufficient intervals between the loads and responsive cycle times of the working stations the sequenced flow of materials in CP has a better compatibility with the pull demand.

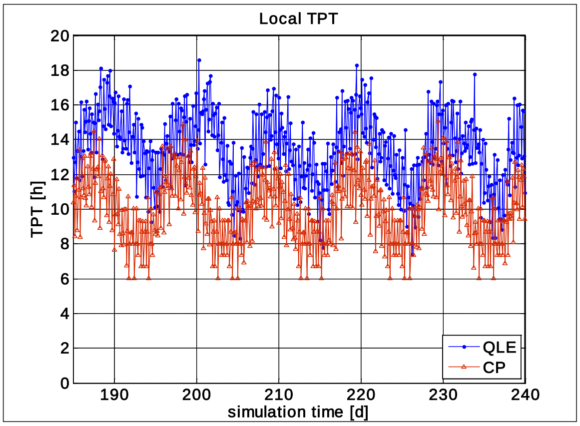

Figure 7: TPT of QLE vs. CP in P_{41}, interval 50 min

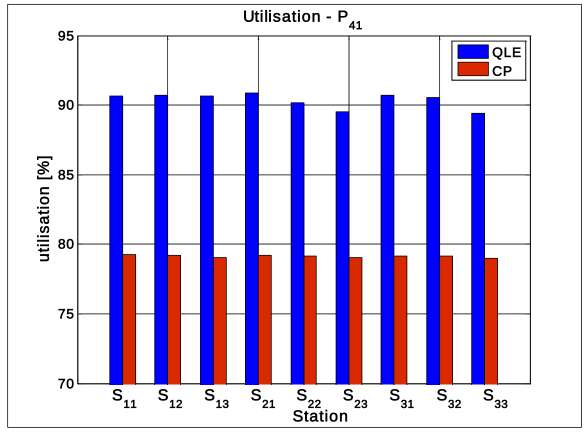

Figure 8: Working percentage of each station in P_{41}

This is because of better regulation of pallets cycling and consequently better availability of them for carrying the materials. The cause of this increase in both global and local TPT for QLE is again the incongruence of material replenishment in OEM and demand pull which makes a big idle time in entrance. Generally, the worse results in QLE method at OEM could be described as follows: Up to the D.C point QLE has a very tiny advantage to the CP, as the load is constant and the processing capacity is enough for the load intervals. However the QLE performance got worse against CP in the P_{41}. This is because of the sequence of replenishment loads. In CP the sequence is always constant, but in QLE method the sequence is dynamic. Since there is no exchange of information between the plants, the demand is no more coordinated with the loading strategy. Eventually, the sequence of loads in CP is more suitable for fulfilling the fluctuating demand, thus the products have less idle time for respective pallets in the entrance inventory of OEM.

Therefore, an improvement should be implemented on the autonomous methods to develop their performances confronting with new dynamic factors in a shop floor or in a network of plants.

Still, the collecting backlog of QLE is 24.6 products while this is 29 for CP. Also the utilisation of QLE method is about 10% higher than CP. These keeps the advantage of autonomous control in its general context, see Figure 8.

Furthermore, to emphasise on the causes and effects of dynamics beside the damping and amplifying activities, one more scenario is experimented as constant loads with shortages for fulfilment or delivery. Following are the rest graphs of the constant loads in upstream with an interval of 1 hour between each alternative product. Here, the difference between two control methods is not rigorous for global TPT, see Figure 9. One hour interval is less than the capacity of stations (cycle times). Hence, no real benefit exists for either method but better application of QLE in utilisation of stations, especially, in P_{41} was seen.

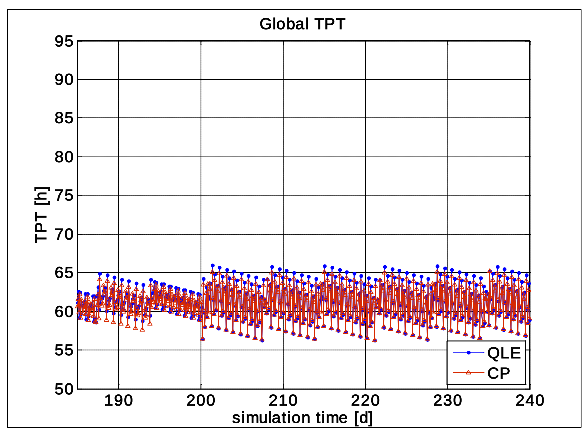

Figure 9: Global TPT of QLE vs. CP in the network

The next graph in Figure 10 is related to the TPT in OEM with the load of 1 hour interval at the first source plant along continuous sinusoidal demands (pull). Based on the mentioned reasons the average TPT of CP here is a bit better than QLE here.

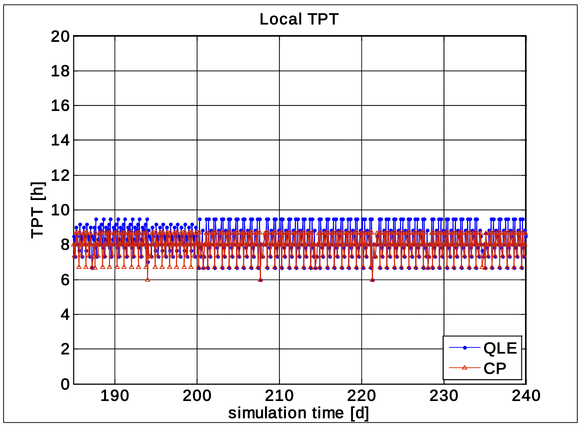

Figure 10: TPT of QLE vs. CP in P_{41}, Interval 1 hour

However, in this case number of backlogs is unacceptable because of the shortages in material replenishment. It means the average backlogs for all products in QLE and CP are equal to 395.33 products. Obviously is not a proper strategy for producing but it shows the different behaviour of the graphs in comparison with the previous loading scenarios. The STD is quite less than before and the sinusoidal effect of the demand is not very much distinguishable. In other words, the fluctuating TPT returns to the intervals of the transportation means and the demand shape is hidden by both shortages and constant replenishments causes.

Regarding the continuality of sine Equation (1) as is seen in Figure 2. It can be noticed, that the visible change of this behaviour and the effect of that on TPTs through the entire network, under different material routing strategies and loads, is quite considerable.

7 Summary

In summary, the current study reproved that autonomous processes and their related control method (QLE here) have a better performance facing fluctuating demand in the global network system, particularly, when the loading is fluctuating as well. On the other hand, sometimes for businesses with constant environment, employment of the autonomous control could be an extra cost and complexity. Although autonomous routing methods gave very promising results in previous works [5,6] capability of them should be improved by coordinated autonomous processes, in order to get more harmonised operations in a production network, especially when with D.C point strategy is employed. It means, either coordination of material flow between both sides of DC (turning point) or enhancement in performance of autonomous control in this specific point seem to be crucial.

The other important result of the paper is the favourable combination of autonomy paradigm with conventional strategies. Actually, exploitation of decoupling point causes a division, in production network or supply chains, between material flow strategies. Respectively, a decline in complexity of the network planning and control will be achieved. Easily the upstream from D.C point could follow a constant push production with a conventional system by reasonable interval, whereas downstream from D.C could have a pull strategy with a flexible and agile production system, by applying autonomous control for routing.

As displayed above, the promising paradigm of autonomy has a cooperative feature with conventional strategies to deal with dynamics. It is exposed that dynamic disturbances are not always some hidden factors. It means practical constraints by themselves could result into worse performance against dynamic environments. This phenomenon is explained here as damping (reduction of dynamic effects) and amplifying (adoption of dynamic behaviour) factors. The main target here was to understand how the existing dynamics could be handled either with causes or effects of them.

Although the level of autonomy and the degree of heterarchical vs. hierarchical decision making are still under investigation, here the necessity of activities' coordination has been seen.

For further studies, still exists a great opportunity for exploiting the autonomy aspects and methods. In the near future application of autonomy in existing strategies will be a mean to achieve business excellences.

Eventually, with the on hand potentials, employment of several levels of autonomy and its freedom in decision making should become under exploration. Application of autonomy in macro-aspects of production networks and their supply strategies, combination of conventional (e.g., with push strategy) in macro-scale as well as autonomous control (e.g., with pull strategy) in micro-scale or vice versa, integration of information and material flow, estimation of the transactions between global and local information flow, transportation capacity, positioning of decoupling point in the corresponding supply chain strategies, sequencing and material routing, as well as lot-size decisions, are some of the open research areas and are fully recommended. By an extension to the autonomy definition, a prospective feature of that could be proactive performances of autonomous processes and objects. This prominent specification could adopt dynamic characteristics against dynamic complexities in the future.

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