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Service Level Agreement (SLA) Chains Supported by Cloud in a Complex Port Ecosystem with Competing Stakeholder Goals: Editorial

C. Peoples[1,*], A. Moore[1] and N. Georgalas[2]

[1]School of Computing, Ulster University, Newtownabbey, United Kingdom
[2]Applied Research, BT Group PLC, Martlesham, United Kingdom

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*Corresponding author. Email: c.peoples@ulster.ac.uk

1. Introduction

Ports play a crucial role in the global economy and in facilitating international trade. However, a port exists within a complex ecosystem and there are challenges in managing operations here for any single objective, with primary goals including operational performance, cost, sustainability, safety, and even satisfaction. Each goal can be aligned with a stakeholder group, and all need to be managed in parallel for an overall effective, satisfying, and efficient port. However, opportunities in the chain of activities at ports which lead to these goals being achieved are not being protected or exploited, and until schemes are put in place to do so, a challenging working and living environment is allowed to persist in and around the port. This is having a damaging impact on both employee motivation and local resident satisfaction [1] [2]. Furthermore, due to the dependencies between each stakeholder, a negative experience for one can lead to a consequential negative reaction for others, and the effectiveness and efficiency of the entire ecosystem begins to decline. From a port management perspective, there is therefore a need to manage port activities without unnecessary delay due to the ripple effect and subsequent reactions on all stakeholders in the ecosystem.

The aim of this article is to consider the complexity of the port environment from the perspective of stakeholders, with a view to recognising the ways that their needs can be targeted in parallel using cloud-driven Service Level Agreements (SLAs).

Port Stakeholders

To contextualise the ways in which a negative situation for one stakeholder can have a wider impact on others, consider a scenario where a ship's arrival at a port is delayed. This is a particularly relevant situation to examine, given that ship reliability is at an all-time low in 2022, with almost 70% of cargo arriving late by June. (To contextualise this, pre-Covid ship delay was experienced only by approximately 20% of cargo [3].) In the event of a late arrival, a ship can be temporarily prevented from docking – the staff may be unavailable to support the docking process, or the physical space may not exist to do so. This will have a subsequent impact on congestion in the yard, with lorries arriving to receive goods from a ship that are not yet available. With a congested yard, any further lorries arriving to remove goods from the warehouse will be unable to enter, and the warehouse space required will not be available for new loads.

In the background of this front-of-house port congestion and delay, port workers involved in receiving the ship at the dock will be unable to take action. Warehouse workers will similarly be unable to move goods, and logistical staff will be unable to perform their roles both within and beyond the port. Staff satisfaction, morale and motivation may be more likely to begin to decline given the lack of progress and the impact this has on their mental health [4].

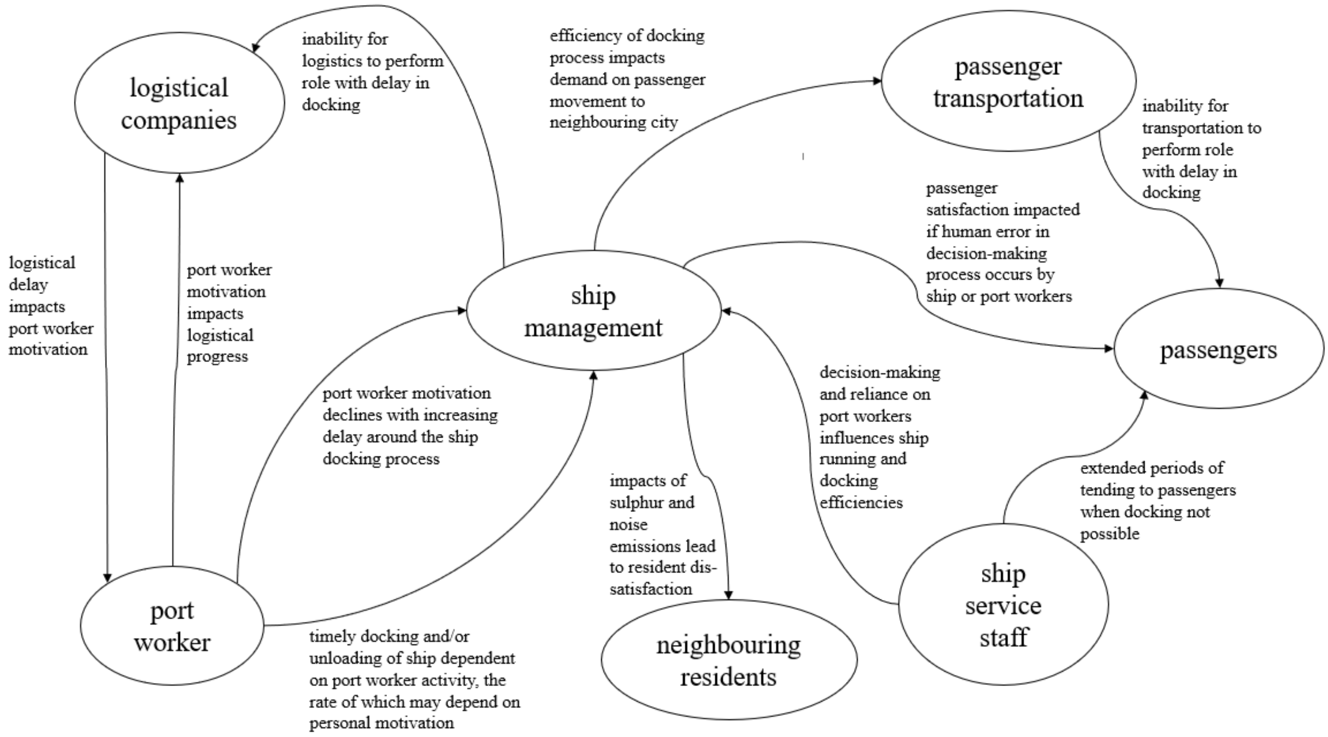

Figure 1. A Selection of Port Stakeholders and their Inter-Dependencies

Further in the background of the port, pollution emissions will be increasing and having a wider environmental impact, with both sulphur and noise from ships, and similar contributions from lorries. Workers in this situation may then be deployed in potentially dangerous spaces for longer than necessary, with danger considered from the perspective of harmful gases, dust and noise, when carrying out their roles [7]. Deeper in the port ecosystem, residents living around the port can similarly become increasingly dissatisfied with and affected by the disruptive and dangerous environment in the nearby vicinity.

In the presence of the ship delay, once docked (as soon as the space is available to do so and port staff are able to support the process), the next scheduled ship may arrive, with the consequence of a subsequent impact due to the unavailability of port workers to handle two ships simultaneously. In a port which accepts a variety of ship types, consider that the first ship is transporting container loads and the second ship is a cruise ship transporting passengers. With the second ship being unable to dock and allow passengers to depart, the local Wi-Fi connection on the ship and in the port area can become overwhelmed. Service staff on the ships, instead of acting in their roles once passengers would normally have left the ship, will instead continue to support passengers, and there is potential that the satisfaction of both stakeholder groups will decline due to inability to proceed as expected. In the meantime, the transportation, such as a bus, waiting to move passengers arriving at the port on the ship into the nearby connecting city will be unable to perform their role in the chain. This will increase congestion in the port, if allowed to enter, or in the area surrounding the port, if not. This can lead to further increased pollution emissions and noise for workers, visitors and residents in the local area. A map of a selection of the conflicting stakeholder objectives at and around a port is presented in Figure 1.

We make assumptions with regard to the priority of stakeholders who are associated with a port in **Figure 2**. We do not wish to indicate that these are the only port stakeholder priorities, however, based on our research and understanding of activities in and around ports, these are the conclusions which we have drawn. The port priorities differ for each stakeholder group, but each has a significant impact on the others, and therefore need to be managed in parallel.

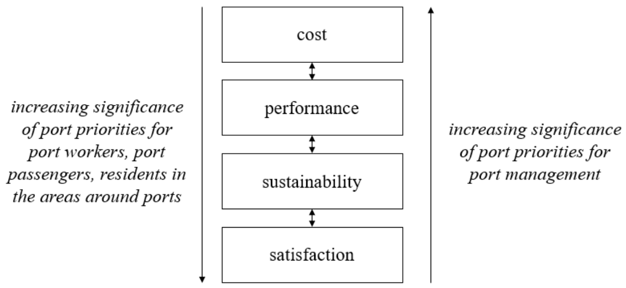

Figure 2. Competing Port Stakeholder Priorities

To provide more context on the alignment of stakeholders (**Figure 1**) with their core priorities when operating within and living around the port (**Figure 2**):

- Port management will ultimately be concerned about the cost of running the port and its performance. Performance is heavily dependent on cost incurred, that is, it improves performance as the number of workers increases, however, at the expense of costs similarly increasing. There is therefore a balance to achieve in relation to both costs and performance from the port management perspective.
- Sustainability is similarly dependent on performance, with more sustainable operations achievable when the port is achieving maximum efficiency and effectiveness. As performance deviates from the planned sequence of activities, sustainability will vary in parallel. The sustainability priority may have variable levels of relevance for port management, and we argue may be of more concern for those working manually within the port and those living in the local port area.
- As performance and sustainability become less optimal, the satisfaction of people living around and working within the port will similarly be impacted. Once satisfaction is impacted, then costs may subsequently be impacted because of change in worker effectiveness due to their lower motivation levels. If their rate of working slows, this will have significant impact on port performance, costs, and sustainability.

In summary, there is a complex set of consequences once any deviation from the expected efficient and synchronised operational scenario occurs. This is not a trivial problem to respond to and the existence of delays impacting a broad stakeholder chain persists across ports. Challenges associated with delays have become a particular problem in the presence of Covid-19, as the supply chain attempts to recover, and pandemic pressures begin to ease [5] [6]. Nonetheless, work is underway to respond to the operational dilemmas at ports, and approaches to responding to the complex management challenge is examined both in the academic literature (e.g., [8] [9]), government reports (e.g., [10]), and recently in the news (e.g., [11]).

Related Work

With a view to understanding the inter-relationships and dependencies between stakeholder activities, Benedicto et al. (2018) simulate port operations, in an approach which accommodates the random variables of climate and those ship-related, in addition to the more predictable shipping characteristics [8]. Based on the inputs, potential alternative strategies to manage the port are considered which prioritise operationality, waiting times, occupancy, and the use of harbour services for an overall optimised approach. Stergiopoulos et al. (2018) discuss the limitations with traffic flow analysis methods at ports in terms of their ability to understand the wider spread impacts of delay experienced by one stakeholder on others [9].

The Office for National Statistics gathered data for the purpose of garnering insights into shipping movements across the largest UK ports; the metrics of interest include port traffic and utilisation, ship movements, port network, hazardous materials, and port delays [10]. Using the data, a ship's behaviour is classified into one of six groups at every stage throughout its journey. The significant piece of data is the likelihood that a ship will be delayed in its arrival at a port – this was able to be detected in up to 70% of test cases.

Further evidencing the complex management challenge of the port ecosystem and the impact of delay on others, Shanghai port has recently been reported as having declining productivity, with subsequent impact for Tesla, Toyota, Lexus, among others [11]. To respond to challenges at the port, a heat map is being used to track supply chain problems which originate at the port.

In relation to the approaches to minimising delays at ports, a significant volume of data is being generated, processed, and assumed stored so that trends in the events and consequences contributing to exposing operation of the port can be tracked. It is not clear whose responsibility the collection, management and storage of the data is, but it is a significant undertaking for a port management team to manage by themselves. Indeed, one of the challenges of managing ports in more effective ways is a consequence of the widespread resistance to the introduction of technology at ports in general [12]. We, therefore, encourage that this becomes the responsibility of a third party dedicated to offering IT services to the port under the agreement of a contract, the service provider.

Using Service Level Agreements (SLAs) to Respond to Complex Stakeholder Chains in Ports

The literature confirms the opportunities to improve operational efficiencies through the introduction of technology into the port domain. However, ports are a unique environment and technology is resisted, as described above. One reason for resistance is the technical ability of staff at the port. The introduction of technology can lead to a need to recruit staff with more technical ability, making those without such skills redundant. This is further exacerbated by the fact that a port is only one link of a supply chain, and even if technical ability is enabled at one port, it may not be similarly enabled at others – in this case, enabling technical solutions at one port will play a redundant role when considering the larger supply chain.

Nonetheless, greater autonomy at ports can be introduced through supporting operations using cloud capability, and providing a repository to collect meta data in and around the port using an Internet of Things (IoT) deployment of sensors. This architecture can provide real-time and pre-emptive detail about the port and the activities which surround it. Underlying this IoT deployment, the IoT management layer will support autonomous decision-making such that the priority objectives in **Figure 2** can be achieved, without any assumption that people at and around the port have the skillsets to operate technical solutions.

We argue that such solutions can be supported using Service Level Agreements (SLA). When used in this context, an SLA is a connected service with a guaranteed level of service, provided for a charge; the customer is compensated in the event that the service is not provided as agreed. Through a relationship with a service provider, a technical service for a port can be provided for a charge, while port staff can use the collected data to support port priorities and autonomous policy-based services will run in the background. The metadata which is collected can be governed by the policies enabled by the service provider on behalf of the port customer, with the service also including configurations in relation to the rate of metadata collection, and decisions on its management (including processing and storage).

Using SLAs, there may be greater potential for operations to execute without delay. If the delay cannot be avoided due to external pressures which are unable to be influenced from within the port, more effective communication and real-time updates will make the most effective decisions in a challenging situation, ideally in advance of causing a problem. In recognition of the variety of stakeholders and inter-dependencies between them in a port, examining the optimum opportunity to manage competing stakeholder demands in parallel is required. In doing so, it may mean that no single priority is optimised but that a balance is achieved for all. For example, with delays across a port from external influences, a basic mode of operation, at least within the port, may be maintainable. It is possible in this event, however, that staff satisfaction may be in decline, and there are opportunities to examine areas for improvement in this regard while waiting for a delayed ship to dock.

The ability to collect meta data which reveals insights into the real-time state of a port can be influenced by the SLA service tier. An SLA offering can be made in terms of: Storage space (GB); Number of meta data metrics collected; Maximum frequency of meta data metrics collection; Platform uptime (%), Cost (£).

The SLA assignment and management process is represented in **Figure 3**. Based on our assumptions in relation to the priorities for each stakeholder, achievement of the priority will be monitored in real time. Deviation in any stakeholder priority score beyond a threshold will lead to a situation of the SLA being adapted. This may take place for one stakeholder or for multiple, reflective of the inter-dependencies between the parties affected.

To use this operational approach, there are assumptions placed on the architecture in place to support it. These include an IoT management framework which can assign and adapt SLAs, SLA fingerprints, and activity traces to monitor the fulfilment of SLA requirements (**Figure 4**).

An SLA instance will be made available for each stakeholder group, and will involve a different SLA instance for each employee group. Each SLA instance will have a bespoke fingerprint. All instances of SLAs for different stakeholders with potentially competing needs, will execute in parallel across the port ecosystem to achieve an overall functioning core. Each SLA may have distinct priorities, with one operating for cost optimisation, another for performance maximisation, and other for sustainability. When one SLA instance fails, a failover system will seek to optimise the possibility of subsequent potentially negative consequences on other stakeholder SLAs. A failure should have a negative impact on as few stakeholders as possible.

There are therefore significant challenges of operating such an approach. Firstly, there is the challenge of forming the correct SLA assignments for each stakeholder. Secondly, there is the challenge of ensuring compatibility of the SLAs offered between the variety

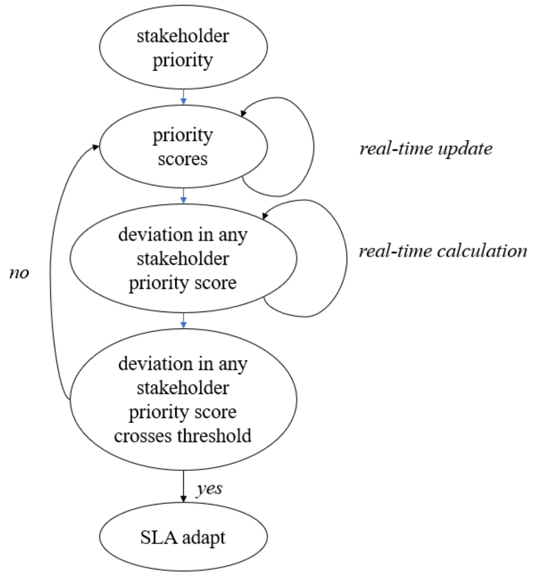

Figure 3. SLA Assignment and Management Process

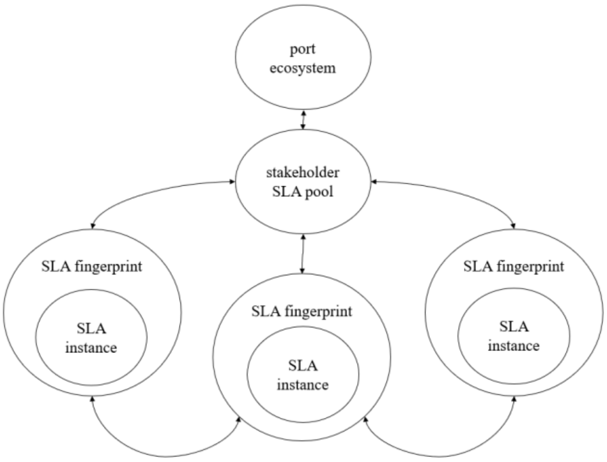

Figure 4. SLA Footprint in the Online Port Ecosystem

of stakeholders at the port. Finally, there is the challenge of managing the SLA assignments in a complementary manner when the SLA for one or more stakeholders fail.

Conclusions and Future Work

The significance of a port in supporting the global supply chain makes it a complex management challenge, even before technology is integrated. The level of technical skills present in a port makes it a prime target to become a site whose technology is outsourced and managed externally. We recognise a gap in technology use across ports in that operations can be governed using SLAs, with a service offering being provided which can support the compatible management of multiple stakeholder goals in parallel. It is the design of the SLAs that we prioritise in our research, in a manner which is complementary between the range of stakeholders within the competitive operational environment.

As each SLA assignment responds to the needs of a particular audience, it may be difficult, if not impossible, to respond to the requirements of all simultaneously. We now move forward with our research through investigating:

> *How to achieve sustainability, cost, operational performance, and satisfaction to a satisfactory degree for all stakeholders simultaneously?*

Each stakeholder goal has, at least on the surface, conflicting factors which work against each other. For example, to amplify performance, cost will be impacted. To promote sustainability, performance will be impacted. To achieve a balance, we have advocated in our prior work [13] that, when staff satisfaction exists, the port can be operated for sustainability, with an assumption that the port is being operated effectively and efficiently, and delays incurred are beyond the capabilities of the port. If staff satisfaction declines below a threshold, on the other hand, a decision can be made to operate for performance objectives, with a view to increasing staff satisfaction and return to a sustainable situation. In this way, while it might be argued that an individual goal is given the focus at any point in time, this has been driven by other competing objectives, and that achieving this multi-stakeholder balance is influenced by the dependencies between each.

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