Assessing Maritime Customs Process Re-Engineering using Agent-Based Simulation

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ABSTRACT

Case studies report that corruption is not easily combated by policy changes, and that reform policies can have unexpected side-effects in practice. Using agent-based simulation, this paper studies potential anti-corruption policies in the maritime customs context. We detail an agent-based simulation calibrated on the processes of an archetypal Mediterranean container port (where in-group relationships contribute to a situation of endemic corruption), and describe insights gained about the costs and benefits of various reform policies. Results from the simulation model provide commentary on cases reported in the literature, and offer novel evaluation of policies involving process re-engineering.

Keywords

policy analysis; agent-based simulation; customs; ethics

1. INTRODUCTION

Despite customs revenue contributing a significant component of public finances, particularly in developing countries, the Organization for Economic Co-operation and Development (OECD) finds that customs efficiency is often hampered by widespread corruption, creating "a major disincentive and obstacle to trade expansion" and leading to "disastrous consequences in terms of national security and public finance" [23]. The literature concludes that customs corruption is not easily combated by policy changes, that reform policies can have unexpected side-effects, and that a broadly-based, systemic approach is required [26, 39].

Our domain of interest is maritime customs, namely the import of sea-based containers. A port, including its customs import processes, is an instance of a complex socio-technical system with multiple stakeholders. The aim of this paper is to explore potential anti-corruption policies in this maritime customs context, focussing on process re-engineering. We describe the design, implementation, and validation of a multiagent-based simulation (MABS) calibrated on evidence from ports in high-corruption Mediterranean countries [10]. The goal of the simulation model is not to simulate precise behaviours or to make quantitative forecasts, but to simulate archetypal process deviations and suggest possible qualitative outcomes of policy measures.

Specifically, we examine a set of localized measures and a set of broader process re-engineering policies. The localized policies include increasing customs employee wage rates, and increasing enforcement and fines. The process re-engineering policies include removing the capability of freight forwarders to select specific (in-group) customs officers to work with, and streamlining processes through the introduction of electronic payment of duties. Results from the simulation model offer multi-factor assessment of such policies in a complex environment with endemic corruption and significant in-group relationships between actors.

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2. BACKGROUND AND CONTEXT

Whenever a process has the opportunity or obligation for people to negotiate, the possibility of corruption arises. According to the World Bank, corruption is "the misuse of public office for private gain" [51], whether (1) *routine* corruption (e.g., bribes for normal or expedited completion of processes); (2) *fraudulent* corruption (e.g., tacit or explicit collusion to reduce fiscal obligations); or (3) *criminal* corruption. The negative repercussions of corruption upon institutions, societies, and nations include poverty, tax evasion, political instability, weakened democracy and rule of law, reduced national competitiveness, and (especially for customs) distortion of trade figures. Further, corruption—whether *collusive* or *coercive*—reinforces disenfranchisement and hinders development, being "one of the most serious barriers to overcoming poverty" with a strong correlation between perceived corruption and per capita income [52].

In order to counter established, widespread corrupt practices, a deeper understanding is required of the processes in which corruption features, together with a deeper understanding of the corrupt practices that occur, within the broad socio-political, socio-economic, governmental and cultural situation [23, 26, 43, 1]. Among case studies, Hungarian researchers noted how government structures can allow for the formation of elite cliques which can design and coordinate entire networks of corruption [25]. Studies in China further explored the influence of corrupt in-group networks which, in situations of collective corruption, tend towards rewriting norms and thus legitimizing further corruption [15]. Indeed, the interconnectedness of actors is an antecedent for collective corruption which in turn can lead to endemic corruption [29]. As such, highly-connected environments may demand a greater level of policy engineering in the form of process redesign, automation, procedural streamlining, and norm change. This need to understand

the nuanced impact of potential policy reforms provides the motivation for our work in the field of maritime customs.

Customs is "the official department that administers and collects the duties levied by a government on imported goods" (Oxford English Dictionary [OED]), and, we might add, to enforce customs regulations. Our motivating domain is maritime customs, specifically import of sea-based containers. A key role in the process of moving a container through customs is that of the *freight forwarder*, a company that manages and organizes shipments for others, sometimes consolidating smaller shipments. The process is primarily based on a match between shipping documents (e.g., bill of lading) and customs documents (e.g., manifest). If this match is made and the shipper and/or consignee (i.e., recipient) are considered trustworthy, then the container may proceed following the payment of standard duties. Otherwise, or if it should be randomly selected, the container is subject to search and may see additional duties or fines. Possible *deviations* from an archetypal customs import process (see Fig. 1) include inaccurate, incomplete, or fictitious documentation; under- or over-inspection; inaccurate value estimation; waiving true fines or imposing additional fines; and delaying or expediting certain containers. In some situations, a whole grey 'parallel customs' system evolves [14, 24].

Policy efforts led by the International Monetary Fund (IMF), OECD, World Customs Organization, and World Bank have focused—not without critique [26]—on reducing trade barriers, reforming trade procedures, and building 'cultures of integrity'. Great care is required in such policy engineering, since, on the one hand, customs corruption has been shown to be not easily combated by policy changes [14, 23], and on the other hand, policy changes can have adverse side-effects, including unexpected fiscal distortions [39, 44].

Agent-Based Models.

In light of these challenges, a benefit of MABS is its potential to give qualitative insights into what-if policy scenarios—scenarios which are not subject to hypothesis-and-test experimentation in the real world [12].

The domain studied, while embedded into a social context and highly influenced by organizational, cultural, and social factors, does not match exactly any of the paradigmatic models for agent-based social simulation identified by Marietto et al. [33]; the closest match is *socio-concrete models*. Rather, simulating deviations in maritime customs may be better characterized not as a social simulation per se, but as simulating social complexity—the structure and norms of what is and is not considered acceptable in the realm of customs processes, and the micro–macro link between (emergent) actor behaviours and policies applied to the system.[1] Our objective is not so much forecasting (as in computational economics) or optimization (as in traditional operations research) but understanding of collective behaviours.

Granted that negotiation is the most common entry point for deviations within customs processes [27], the study of negotiation is multi-faceted, including political science, economics, policy research, psychology, and computer science. Sycara and Dai [50] report on efforts to unify research in behavioural and computational (including agent) communities. While the maritime customs domain holds a rich vein of research in the dynamics of bargaining situations, our objective is not to study deeply the negotiation itself but rather to capture agent interactions within the customs process in order to study policy analysis questions.

Agent-based models and MABS have been successful in port management (e.g., [21, 20]), maritime container shipment (e.g., [31]), and policy analysis in transport (e.g., [3]). Agent-based simulation has also been used to study corruption. Hammond [18] develops an agent-based population model in an effort to explain shifts in corruption levels. Corruption is modelled as a simple, game-theoretic repeated interaction on the micro level. In a tax-evasion domain, endogenous shifts in global corruption levels are observed as emerging from the micro-behaviour. Among studies of social behaviour, Abdallah et al. [1] show that peer-punishment is more effective than an overly strong centralized punishment in promoting cooperation, if actors are able to bribe centralized authorities. It will be interesting to extend Hammond's direction and explore in- and out-group peer-effects in customs departments.

Our previous work, Harb et al. [19], presented a methodological approach for choosing a modelling paradigm for policy analysis, using the Port of Beirut as a case study. In Srour and Yorke-Smith [49] we went on to outline the design of a MABS of the customs processes of a container port; here we extend the model to include, among other factors, coercive as well as collusive corruption, develop the design to an implemented simulation, and report the results. Other works that study practices in the same customs context do not aim to build a behavioural simulation [42, 36, 8].

Situngkir [48] is interested in the link between corrupt behaviours in individual agents and the normative societal and cultural environment in which they interact. He builds a MABS inspired by corrupt bureaucrats in Indonesia and obtains system-wide results. Balke et al. [2] discuss in detail norms in agent-based simulation, and Norling et al. [35], for instance, seek to add more 'human-like' decision making strategies, while Dignum et al. [9] and subsequent works emphasize models that include culture.

Archetypal Port.

Our work focuses on ports in high-corruption Mediterranean countries. Individually the ports that we focus on serve in the range of 750,000 to 1.5M Twenty-foot Equivalent Units (TEUs) per year and with values greater than $200M. This is the size of terminal that begins to have a significant impact on the economics of the country in which it is situated. The Port of Beirut, Lebanon, for example, accounts for nearly 90% of Lebanon's customs income, and is a large contributor to Value Added Tax, the largest source of government revenue [40]; whereas "widespread corruption" is reported at the Customs Department [16].

Our data gathering aimed to characterize the domain and the processes of interest, and to elicit structural, environmental, institutional, and behavioural knowledge necessary to build a MABS. We sought information in three sources [11]: observation and data collection from the target system (i.e., the port), bibliographical review (i.e., theories), and domain experts. The material found included press articles

[1] In the taxonomy of Davidsson et al. [7], the domain is 'social system and organizations'; the end-user is 'scientists' and, perhaps, 'policy makers'; the purpose is 'prediction' and 'analysis'; the simulated entity is 'living'; the number of agent types is a small finite number; the structure is peer-to-peer, hierarchal; agents communicate; the input data is mostly artificial; the present maturity is 'laboratory experiments'.

on issues pertaining to practices at ports in our area of interest [38, 32, 6, 24, 17] and ethnography as reported by ourselves [19], Diab et al. [8], and others [46].

Target observation. The data obtained directly from the target system were published statistics including total number of TEUs per month, value, and breakdown by type, and average time at the port; statistics about the staffing levels; and customs tariffs, fees, and fines. It comes as no surprise that efforts to collect empirical data by observation (e.g., sampling containers and following their progresses) have not been successful; in view of the sensitivity of questions in the domain, this kind of empirical study is unlikely.

Source review. While jurisdictions differ in their regulations and procedures, nearly all ports have similar import–export processes [34], which centre on a match between manifest and declaration. Nearly all ports have an IT system [53], usually divided into two parts: a customs clearance system that maintains the customs records (the manifest), and a portal that allows submission of the required bill-of-lading documents. We use the terms *LIGHT* and *STAR* to differentiate the two systems, respectively. The widest differences between jurisdictions are taxation schemes. Fig. 1 depicts the import process that we use as the archetypal import process underlying the MABS.

Domain experts. We conducted a set of approximately ten semi-structured, exploratory interviews with customs brokers, freight forwarders, longshoremen (i.e., the workers who physically move containers), and Customs Officers at a port within our region of interest [19]. From these interviews we found that the process of moving the container from a ship is physically separated from the process of clearing the container through customs. As such, the MABS includes the role of the customs agency, but excludes the role of the container terminal operator.

The actors in the import–export processes are listed in Table 1. Interviewees, when feeling able to speak with some freedom, reported a systemic norm of deviations in import–export process. Customs Officers in practice have greater discretion than their job description states. It was considered routine to engage in 'wasta' [32]—exploitation of influence, political (or other) power, connections—or to offer a bribe or a 'baksheesh'—a widespread practice "[of] a small sum of money given as alms, a tip, or a bribe" (OED).

3. POLICY MEASURES AND METRICS

The goal of our simulation is analysis of policies designed to combat corruption. As noted in Sect. 2, policy measures to reform customs tend to be in the areas of trade facilitation or broad anti-corruption efforts. Specific areas where new policies may be applied, or existing policies enforced, include [51, 28, 27, 23]: (1) computerized data systems, (2) auditing, (3) sanctions, (4) role separation, (5) Customs Officer wages, (6) declaration and monitoring of assets for Customs Officers, (7) training, (8) culture of integrity (e.g., Code of Ethics), (9) legislative reforms, (10) legal reforms, (11) tax and tariff reform, (12) simplification of administrative procedures[2], (13) increased accountability and transparency (e.g., process documentation), (14) public awareness, (15) regular stakeholder meetings, (16) an independent complaints authority, and (17) media freedom.

[2]The length and the complexity of the import process is significant, since "systems and procedures appeared to have evolved to maximise the number of steps and approvals—to create as many opportunities as possible for negotiationbetween traders and customs officials " [23].

Owner	**Excise officer**
Owner's agent	**Head of Excise**
Freight forwarder	Customs broker
Shipping company	Longshoremen
Vessel captain	Warehouse employees
Clearance Agency officer	Port security staff
Customs Agency officer	Recipient (consignee)
Head of Customs	Police officer
Inspection officer	Customs audit officer
Head of Inspection	Policy maker

Table 1: Actors identified in maritime imports process. Bold denotes actors in the simulation.

Principled means are required to evaluate and compare specific policy measures. We formulated the following metrics to assess evaluation of policy measures for import–export processes, based on the literature (e.g., [30]), reflection over published measured data available, and interviewees' statements: (1) end-to-end time for an item to clear customs, (2) time difference (usually, delay) from desired date of receipt, (3) cost for an item to clear customs, including any corruption costs, e.g., bribes, that can be quantified, (4) number and type of deviations from published process, (5) number of illegal or misdeclared ('deviant') containers, (6) percentage of deviant containers not detected (i.e., allowed to enter the country), (7) amount of revenue obtained by customs, and (8) cost of enforcement (e.g., measured by the total salary of customs staff, plus enforcement actions).

4. DESIGN AND VALIDATION

In this section we describe the design (following [49]) and validation of a MABS for containers passing through the maritime customs import process. We take each shipment as analogous to a round in a sequential bargaining game. Each shipment brings the opportunity for actors to negotiate, or not. The simulation scope is a subset of the full maritime import process, in order to focus on the key actors, processes, and negotiation opportunities.

The most relevant **artefacts** are the owner's declaration, the bill of lading, the *IM4 folder*—which represents a container in the customs process shown in Fig. 1, and which consists of the invoice, packing list, various registration and identity verification documents, and a declaration of value—and the various customs orders and receipts. All these artefacts are commonly in electronic form.

Of the **actors** listed in Table 1, we selected the eight in bold for inclusion in the simulation. Our reasons for excluding explicit representation of other actors were: (1) some actors can be subsumed by others with little loss of generality, e.g., the owner can be represented by the owner's agent; (2) some actors have a role in the maritime import process but their role in the customs sub-process is limited, e.g., the vessel captain; (3) the role of some actors can be emulated by a non-agent entity, e.g., the audit officer can be emulated by the probability of a customs employee being audited; (4) simplification by focusing on the key actors; and (5) limiting the scope of the simulation in order to obtain explanation for observed results. Future work is to expand the simulation's

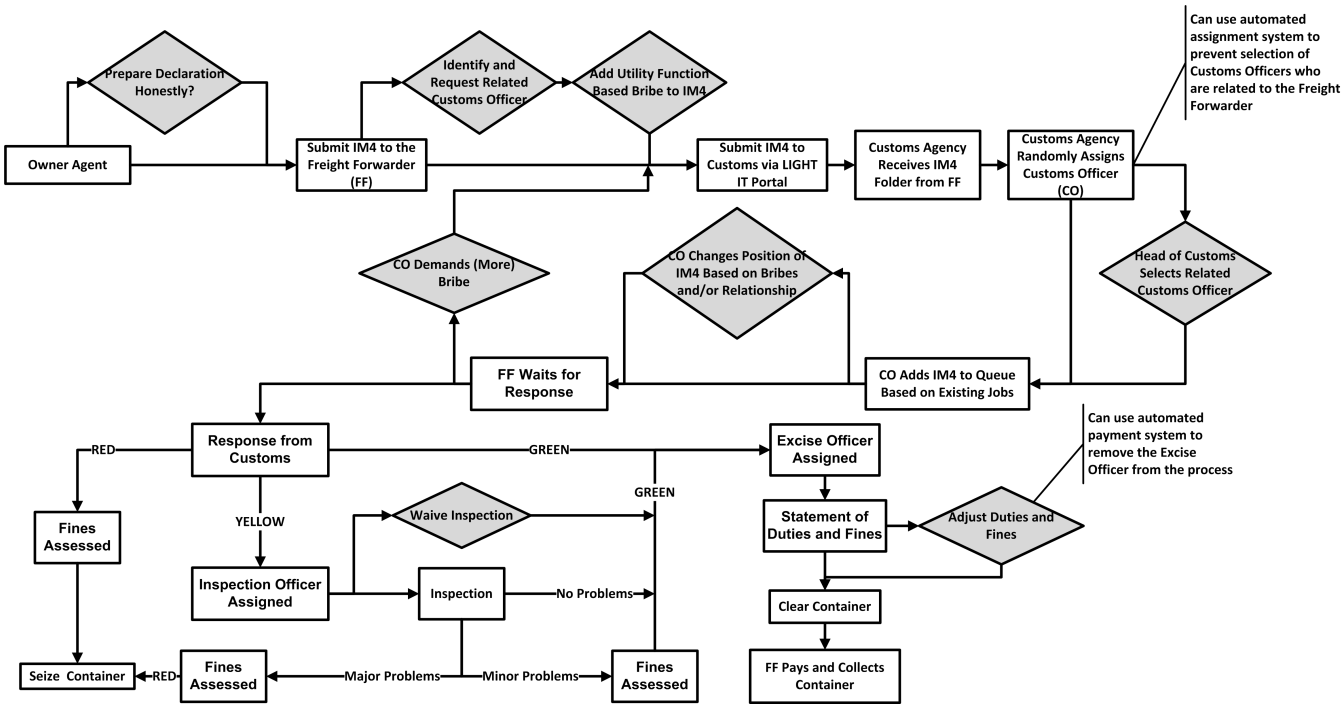

Figure 1: Flowchart of import process at archetypal port as implemented in the MABS.

scope to include, for instance, an explicit representation of the customs audit officer.

Owner's agent (OA). Decides what to declare based on the tariff for the actual container contents, and estimates of the cost of bribes necessary and probability of inspection.

Freight forwarder (FF). Offers bribe to CO (part of which will be passed on to other actors in customs) to expedite container if its due date is close. Offer a bribe to HCO to obtain assignment to a preferred CO, i.e., a CO to whom the FF has a relationship. Offers bribe to CO obtain a GREEN decision if the expected cost of doing so is less than the cost of fines and fees; assumes that all COs will accept a bribe of sufficient amount (a warranted assumption when corruption is endemic). If the CO demands, will increase bribe amount up to the maximum amount where expected cost would exceed expected value. Routinely offers baksheesh. Note that we fold the important role of the customs broker [24] into the FF.

Customs Agency officer (CO). Unless opposed to bribes in principle, accepts any bribe of sufficient amount, to either expedite the container, waive inspection, or change decision outcome. May demand a bribe if none offered or if its amount is too low. May impose an unnecessary inspection unless bribed. Works slowly on a container unless given a baksheesh. Always declares GREEN a container whose owner or consignee is related closely enough.

Head of Customs (HCO). Supportive of the COs, turns blind eye to non-standard practices [24]. Does not overrule a CO's decision, except for RED decisions for a sufficient bribe. Will override IT system's assignment of container to a CO for a sufficient bribe. HIO and HEO behave similarly.

Inspection officer (IO). Unless opposed to bribes in principle, accepts any bribe of sufficient amount, to waive or expedite the inspection, to or report a different contents than the actual found. Works slowly unless given a baksheesh.

Excise officer (EO). Unless opposed to bribes in principle, accepts any bribe of sufficient amount, to set lower duty than the published tariff rules. Works slowly without baksheesh.

At the heart of the simulation are the actors' progression through the documented processes for each shipment, the points of possible deviation, the decisions whether to engage in (or how to respond to) non-standard practices, and the negotiation that may ensue. We simulate the main, documented customs **process** as follows (Fig. 1): (1) owner's agent submits IM4 to the freight forwarder company, which assigns a specific FF agent; (2) FF submits IM4 to customs agency via the *LIGHT* IT portal; (3) *LIGHT* assigns IM4 to a specific CO; (4) CO sees output of the *STAR* IT system and can override: the decision is RED (fines imposed, seize container), YELLOW (inspect container), or GREEN (approve container, duty imposed); (5) if inspection is required, *LIGHT* assigns a specific IO; (6) the IO inspects the container and sends the report to the CO via *STAR*; (7) the CO revises a YELLOW decision to RED or GREEN and informs the FF; (8) approved GREEN containers proceed to the Excise Department and are assigned by *LIGHT* to a specific EO; (9) the EO computes the final duty, fines (if any), and other costs (handling, storage, etc.) and informs the FF; (10) the FF pays the due amount (plus interest, if applicable); and (11) the CO approves the release of the container. Note that the heads of the respective departments can override both the assignment of officers (by *LIGHT*) and the decisions of officers (in *STAR*).

Deviations, shown in grey in Fig. 1, can occur from the documented process as follows. First, the FF can offer bribes to attempt to obtain its preferred CO, to expedite the container, or to have a deviant container pass through

as GREEN. Second, the HCO can accept a bribe and assign the preferred CO. Third, the CO can accept a bribe (collusive), or it can demand (more) bribe (coercive). Fourth, the IO can waive, expedite, or report differently the inspection. Fifth, the EO can change the amount due.

Audits occur, randomly, at two points in the process. First, the IO's inspection can be audited. We assume that the audit is effective, and will find the actual container contents and value. Since IO could have legitimately missed something in the container, it receives a penalty if it repeatedly is audited as 'failing' in its inspections. The second audit point is after the CO's decision. Again we assume the audit is effective. The CO receives a penalty if its decision differs from the facts available to it. The audits constitute a learning opportunity: the deviational behaviour of all customs actors are reinforced if they are not caught by audit, but the behaviour is reduced if caught. For example, a CO that accepted a bribe and was not caught is more likely to accept bribes in future, but one that was caught is less likely. For the FF, whether a deviant container made it through as GREEN or was stopped as RED (whether by a customs employee or by audit) is a learning opportunity about bribe success and bribe amounts.

In-group relationships. The degree to which two agents share an affinity, and the obligations that come from such an in-group relationship, is a cornerstone of business and society in all Arab and many other Mediterranean countries [46, 22, 26]. As noted earlier, interconnectedness of actors is an antecedent for various forms of corruption. We capture such relationships by a simple model of each agent's sect, hometown, and clan membership. Based on the strength of the overall connection between two agents, the propensity to offer, accept, and demand bribes, the bribe amounts, and customs actor behaviours (e.g., speed of work, inspection decisions, assessed tariff levels), may all change. Notably, the strongest component of relationship is familial. If two agents hail from the same family, then culture can demand that they selflessly seek the welfare of the other, such as by a CO accepting a bribe even of negative expected value.

Assumptions.

The scope of the system simulated is deliberately restricted to the customs import process. Our main assumption is that to begin to answer the questions of interest, we do not need to simulate a larger cross-section of society, nor simulate the whole maritime import process. We also take the approach that we do not need to model in detail each actor's internal cognition and mental state (e.g., beliefs, desires, norms, goals)—just sufficiently to capture deviational practices. We hold further that process deviations can be understood on the basis of analysis of individual initiatives of the agents involved in those processes. That is, while we recognize the significance of group/organizational modelling, we hold that individual-level modelling can give insight into the effects of process deviations.

We briefly mention further assumptions. First, which actors negotiate with which others, especially outside of documented process interactions? We assume that negotiation can occur at each point in the process, but we do not consider negotiation to bypass the process entirely, i.e., so-called 'grey containers'. Second, adaptive behaviour is limited: agents learn from previous 'rounds', but they do not adapt to others' behaviours. For example, the propensity to offer a bribe will increase as bribes are accepted, in general; however, the propensity to offer a bribe to a *specific* CO will not differ from the general propensity, unless there is a relationship between the agents. Third, non-monetary exchanges (e.g., gift of jewellery) are considered as the equivalent monetary value. Further, since the literature indicates that bribes are more prevalent than threats, we do not consider the latter. Fourth, relational capital (wasta) is modelled as a probability regarding whether two agents have an in-group connection (e.g., clan). Because of the sensitivity and complexity of the issue, we decided to not consider patronage. Fifth, all agents of the same type, e.g., all FF agents, operate in the same way and follow the same negotiation model. Although an agent's 'personality' is captured by modelling its propensity to corruption, its experience of past containers, and its in-group characteristics, we do not yet consider emotive state.

Implementation and Validation.

The simulation was implemented using the Java-based agent toolkit Jadex [37]. Compared with dedicated MABS environments (e.g., NetLogo, RePast), Jadex readily allows BDI-style agents, i.e., agents with explicit representations of beliefs, goals, and plans. It has in-built support for simulation [4]. We developed a prototype, then the full MABS.

Verification and validation (V&V) were performed on each subpart and on the overall MABS by the development team, following the process of Sargent [41]. Ideally, domain experts are involved in V&V. Due to the nature of the domain problem, it proved too sensitive a matter—in part because of ongoing media reporting of deviations at the port [17]—to involve any of our earlier interviewees. We did consult consignees who had recent experience of importing goods.

Data validity. The validity of data used to build the model fell into two extremes. On the one hand, data about tariff rates, for instance, came from official sources and is considered fully reliable. On the other hand, data about bribe amounts came from interview, anecdotal, and media sources, and, despite our efforts to triangulate, is necessarily approximate. Fortunately, our aim is not to simulate behaviours precisely or make quantitative forecasts, but to simulate archetypal process deviations.

Conceptual model validation. Regarding the simulation model design, again it proved infeasible to have the review of domain experts. However, a process flowchart representation of the simulation model was examined by independent individuals familiar with the port. Further, an agent's actions were traced longitudinally through simulation runs, for each type of agent.

Implementation verification. We followed standard practices, including code review, modular verification, and testing of extreme parameter values. Notably the latter tested 0% and 100% for percentage parameters.

Operational validity. In our case, the MABS intends to give qualitative projections into what-if policy scenarios. At the system level, it was not possible to compare the trace of a simulated container with actual traces, since, as noted earlier, efforts to obtain traces through the actual process were unsuccessful. Beyond our previous work [49], there are no other models of the studied system to compare with, other than an abstracted Petri net model [36] and scheduling models of other processes at the port. Third, it is not meaning-

Type	Duty	Percentage
Personal possessions	Exempt	5%
Jewellery	Exempt	5%
Appliances	Standard	10%
Furniture	Standard	5%
Computers	Exempt	10%
Foodstuffs (perishable)	Standard/Punitive	15%
Raw commodities	Exempt	25%
Gold	Standard	5%
Clothing	Standard	15%
Automobiles	High	10%

Table 2: Container distribution mix.

Parameter	Baseline value
Illicit container %	10%
Standard tariff rate	5–10%
VAT rate	10%
Fine penalty	10x tariff
Chance of inspection	25%
Inspection success	80%
Work-slow ratio	3 times
CO collusive propensity	75%
CO coercive propensity	60%
Chance FF & CO related	2%
Chance of audit	2%
Audit penalty	6x salary

Table 3: Main simulation parameters.

ful to directly compare output measures from the simulation with the modelled system (e.g., reported monthly Key Performance Indicators [KPIs]), due to the level of fidelity of the simulation and its scope. However, we did explore qualitative correlation with reported outcomes, such as decreasing duties on gasoline [13].

5. INSIGHTS ON POLICY MEASURES

In this section we exploit the MABS to analyze reform policies in maritime customs. We model the contents of containers as falling into ten categories, giving a representative spread across attributes (small/large items, low/high value, perishable/not) and tariffs (exempt, standard, punitive) [30], and estimated the distribution of these categories from published statistics (Table 2). Table 3 gives the baseline parameter values extrapolated from the target system.

The baseline parameters gave the values of Key Performance Indicators of Table 4. Results reported are averaged over 100 runs of 1600 containers each. This number of containers corresponds to approximately two months of simulated time. The number of runs was empirically sufficient for variation in results to converge to a small value. We recorded the metrics listed in Sect. 3 and report them as the average per container, with the exception of # Deviant and % Not Caught, which reflect the total number of mis-declared or illicit containers (out of 160,000 across all the runs), and the percentage of those deviant containers that were accepted with an outcome of GREEN. Enforcement cost, not shown for space reasons, is dominated by customs salaries.

Of the areas for policy measures noted earlier, some have been already implemented in the archetypal port (e.g., computerized data systems, process documentation) or exist in the country (e.g., media freedom, complaints hotline). Others (e.g., legal reform) are out of scope of the simulation. We therefore focused on two areas of policy reform: (1) localized measures, including auditing, sanctions, Customs Officer wages, and tariff reform; and (2) process re-engineering, including (further) role separation, and simplification of administrative procedures. We model some policies by their proxy effects on the simulation. Specifically, policies such as training and fostering a culture of integrity we model by their effect on actors' propensity to corruption.

Localized Policy Changes.

For each experiment in changing a policy, Table 4 provides the KPI results for a representative choice of policy values.

Honesty vs. corruption. First we explore the impact of the containers submitted to the customs department. The direct cost of corruption—baksheesh and bribes, besides additional delays (which we do not monetize)—in the baseline scenario is approximately $500 per container. If the percentage of illicit containers increases, the cost (to FF) and bribe levels increase as do the number of deviant containers—although, of those deviant containers, only 76% are admitted. If the container owner is less willing ('only' 50%) to permit the FF to offer a bribe on her behalf, the consequence of note is that the number of deviant containers decreases; other metrics remain the similar to the baseline case. Delays increase if the owner is unwilling to offer even baksheesh.

Next, we consider policies that affect the honesty of Customs Officers. The effect of the propensity of CO agents to accept a bribe has, as expected, a direct bearing on the number of deviant containers that pass through customs, and on customs revenue. If the collusiveness of COs decrease, i.e., COs are less likely to accept a bribe, then the bribe level and number of deviations go down; other metrics remain as in the baseline case. If the coerciveness of COs decreases, i.e., COs are less likely to demand a (larger) bribe, then cost and revenue increase, bribe levels decrease, and fewer deviations occur. Notably, fewer illicit containers receive GREEN, while more misdeclared containers receive GREEN. We attribute this to COs accepting fewer bribes, and so more containers being inspected, and therefore the corruption of IOs having a greater influence.

Tariff levels. As their level rises, the incentive to avoid tariffs increases—in a system where an alternative (deviant) path of container clearance exists. We observe an increase in bribe level and in delay, presumably due to FFs having more incentive to negotiate with the CO. Revenue increases, supposing that the level of imports is unaffected by the tariff level (we also experimented with scenarios where container imports have a negative elasticity to tariff increases; results not reported here). Overall, increasing tariffs can be seen as not being an effective policy in that it not only increases bribes, but will certainly make the port less competitive as importers' costs grow.

Fine levels. Akin to tariffs, as the fine level rises for deviant containers, the incentive to avoid a fine (by acting honestly) increases, but so does the incentive to offer larger bribes (to better ensure the container is not found to be RED). As a result, the customs revenue goes up significantly while the bribe level goes up only moderately. Other metrics remain similar to the baseline case.

Experiment	Time (hrs)	Delay (hrs)	Cost ($)	Deviations	#Deviant (% Not Caught)	Revenue ($)	Bribe ($)
baseline	109	19	26029	12.7	20834 (81%)	18277	503
high illicit	104	10	60151	12.4	144546 (76%)	49551	789
OA honesty	108	19	25962	12.9	18695 (80%)	18443	502
low corruption	106	17	27027	11.9	21038 (78%)	19360	474
low coercive	108	18	27134	12.1	20806 (79%)	19508	463
higher tariff (x4)	110	23	62218	13.0	20799 (81%)	54436	506
punitive fines	108	19	35977	12.8	21085 (81%)	28235	510
more inspection	56	4	30005	8.9	20868 (62%)	20886	1139
perfect inspection	107	18	26605	12.9	20952 (80%)	18822	505
more staff	106	18	26037	12.3	20598 (81%)	18369	492
higher salary	110	19	29878	12.6	20861 (86%)	17232	2475
more audits	107	16	54926	10.1	20453 (28%)	47354	462
many more audits	93	10	41709	5.8	20416 (19%)	33982	625
higher penalties	109	19	50169	12.2	20762 (42%)	42509	502
stronger IT	102	16	26799	11.2	21419 (80%)	19014	495
electronic payment	60	7	26041	11.0	21097 (82%)	18314	503
IT & electronic	57	5	26698	9.5	21028 (80%)	18926	495

Table 4: Snapshot KPI results for baseline scenario, localized policy changes, and process re-engineering.

Chance of inspection. As the number of inspections increase, the percentage of deviant containers found GREEN decreases from 80% in the baseline case to 62%. This decrease, however, is not as substantial as the comparative increase in bribes. Thus, rather than being incentivized to act honestly, the FFs increase bribes to avoid the inspection. Hence, customs revenue remains consistent with the baseline case while bribe levels and increase substantially. Note that the apparent drop in deviations is only the headline figure of the total number, because deviation types such as work-slow deviations, protracted bribe negotiation, and extra inspections and reduced by the larger bribes. Positively, in one sense, delay decreases since containers are being expedited by the CO and inspections waived.

Second, as the quality (i.e., thoroughness) of inspections improves, no change is seen relative to the baseline case. This is likely due to the endemic corruption leading to only a small number of containers actually being inspected.

Customs department size. Adding more staff to the customs department does increase capacity, at the cost of increased salary. The corruption effects (e.g., work-slow, negotiation delays, improper container prioritization) hamper any increase in container throughput. There is only a marginal effect on corruption, since a FF can still influence which of the increase pool of COs is assigned to a container.

Wage scale. Substantially increasing salary, by an order of magnitude greater than the current schedule of bribes, has the effect of making CO agents unlikely to risk accepting a bribe in the short term—until the bribe schedule adapts in the medium term. Salary cost obviously also increases.

Chance of audit. We expected that increased risk of being (honestly) audited will make customs agents less likely to accept bribes. The value of the bribes, however, shows an interesting pattern with an initial decrease in the bribe levels with a moderate number of audits, but with a large number of audits, the bribe levels increase, while both the revenue and costs decrease. We attribute this observation to a greater number of learning opportunities for the customs employees and for the FFs, whose interactions then emerge into a new stable state of higher bribes, to outweigh the greater expected cost if caught. In all cases, more audits ensure that a low percentage of deviant containers receive a GREEN decision. Although enforcement cost increases and the audits take time, overall the delay decreases. We attribute this to less negotiation between FF and CO, and less slow-working by customs staff.

Level of penalty on corrupt customs actors. The baseline scenario has a flat penalty of 6 times monthly salary for COs, if an audit discovers impropriety. Increasing the penalty has an effect much like increasing the chance of audit, although the magnitude of its effect is smaller.

Process Re-Engineering.

Granted that process re-engineering (often, simplification) is an important means to reduce the opportunities for process deviations [23], an advantage of MABS is their use in qualitative predictions of (side-)effects in novel situations, for which other types of models (e.g., equation-based) do not apply because of the novelty [12].

Strengthening *LIGHT* IT system. First, suppose that the *LIGHT* IT system is modified such that the Head of Customs cannot override allocations of containers to Customs Officers made by the system. The effect is that the relationship between FF and CO is likely to be reduced. The observed consequence is that deviations decrease, together with bribe levels and delay decrease. There is a small increase in revenue. Enforcement costs see a minor increase.

Streamlining payment sub-process. Second, suppose that the way FF pay for cleared containers is modified such that Excise Officers no longer have an intermediary role. Rather, when notified of the total payment due, the FF submits the payment electronically. The effect is that the opportunity for EOs to modify (reduce) or solicit for a cut of the payment is removed. We also expect that the automation in the payment process will accelerate the overall customs process. Indeed, the observed consequence is a sizeable decrease in delay (from 19 [baseline] to 7 hours) and a decrease in the number of deviations.

Combining the two process re-engineering policies is surprisingly effective at further reducing delay and decreasing the number of deviations: average delay drops to 5 hours and the number of deviations to 9.5.

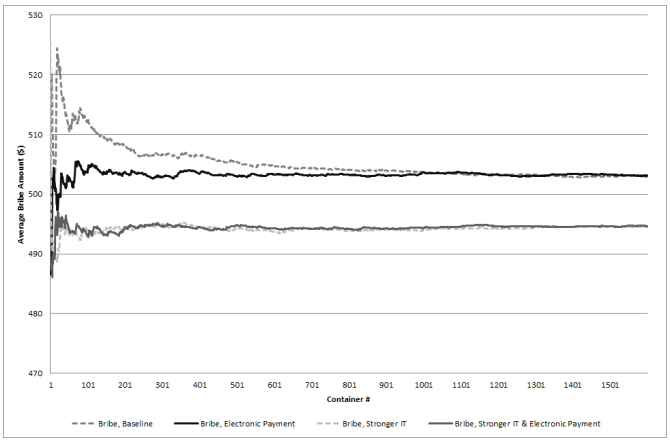

Figure 2: Process re-engineering effects on bribe level. Cumulative averages per container as averaged over 100 runs of 1600 containers.

Fig. 2 highlights the impact of these different policy re-engineering strategies on the cumulative average of the bribe level per container across the 1600 containers in each simulation run. Following the initial period (approximately the first 50 containers) where the system moves into steady state, the effect of the actors' adaptivity can be observed, until the bribe level reaches an equilibrium average value. Strengthening the *LIGHT* system leads to a lower equilibrium average bribe level, whereas streamlining the payments leads to faster convergence but the equilibrium level is the same as in the baseline. We attribute this same level as due to the limited opportunity EOs have to influence bribe levels, being the last customs department actor in the import process and the actor receiving the last cut of the bribe pie. Note that other KPIs, e.g., time and delay, do have different values as a direct effect of the electronic payments.

We conclude that many of the localized policy measures examined are impotent in a situation of endemic corruption—and can exhibit unexpected side-effects—whereas selected process re-engineering offers more promise because it can reduce the frequency of opportunities for deviation. Only a change in internal culture and norms, or rigorous and honest audits with the threat of sizeable penalties, deters customs staff from the lure of collusive or coercive corruption. The web of corruption thickens as in-group relationships increase, suggesting further study on the causes and effects of such relationships [32, 46, 29].

6. SUMMARY AND OUTLOOK

Our objective in this paper was to use agent-based simulation to explore the impact of reform policy measures on maritime customs. We detailed the design of a MABS of customs imports, based on processes and deviations from them at an archetypal Mediterranean port in a context of widespread corruption. The simulation models collusive and coercive corruption, in-group relationships, and agents' adaptive behaviours in negotiation.

Simulation enables us to provide important qualitative insights into what-if policy scenarios, which are not readily subject to hypothesis-and-test experimentation in the real world. Taken as a whole, our observed results correlate with the literature that "localized punitive- or incentive-based policies cannot correct a situation of widespread corruption" [23]. We found that modifying existing process factors such as fines and wage levels had little effect in a situation of endemic corruption, that measures such as inspections could increase customs revenue but not reduce deviations—rather, bribe amounts simply increased—and that deviations could be reduced only by increasing audits, which can have unexpected side-effects. Further, in practice in such a setting, the auditors are themselves open to corruption [1]. Focusing on process re-engineering was found to offer more promise. Strengthening the autonomy of the IT system reduced bribe levels and deviations, while streamlining processes through the introduction of electronic payment of duties reduced both deviations and delays although not the bribe levels.

The results of our study are subject to a set of limitations: (1) scope of the MABS, e.g., the focus on bi-lateral bribe-based deviations; (2) accuracy of data, e.g., about deviations from the published process—despite the efforts towards triangulation reported in Sect. 2, the nature of non-standard behaviour makes deviant behaviour difficult to document and harder still to verify; (3) fidelity of agent behaviour modelled, particularly in regard to motivations/goals, and negotiation patterns; (4) actors not explicitly modelled, and stakeholders at other levels outside the customs import process (e.g., societal, policy makers); (5) factors excluded from the MABS, such as patronage; and (6) calibration and validation on a single port instance.

While recognizing the limitations of a MABS, our results to date serve as the basis for a broader stakeholder discussion. Ultimately, we want to understand not only the potential effectiveness of reform measures, but their impact at multiple levels to the behaviours of the stakeholders of the port socio-technical system. Notably, in the longer term, stakeholders with power to set policy must be engaged in order for there to be application of any policy measures.

We mention four lines of ongoing and future work. First, to expand the scope of simulation by, for instance, including additional actors and enhancing individual agent negotiation behaviours. Second, to examine in detail the effect of in-group relationship on policy efficacy, and to consider specific reform policies in the context of high and low levels of such relationships and with specific social network structures. Third, to include export processes, since containers imported into one port have been exported from another. Lastly, to compare behaviours to other contexts [38]. While process deviations similar to our archetypal port are widespread across the Mediterranean and elsewhere [10, 47, 5, 45], we posit that MABS can give insight into the relative effectiveness of policies in different socio-political, socio-economic, governmental, and cultural contexts.

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