Foundation for rapidly expanding material handling facilities

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ABSTRACT The Hatch Product Transport (HPT) system is a highly flexible and configurable route selection and sequencing system for controlling large bulk material handling facilities. The system has a generic control algorithm that can be configured to suit any material handling facility. It can also be easily reconfigured to cater to plant expansion or modifications without incurring significant disruption to the existing production, costs in testing, and re-commissioning, thus achieving cost savings throughout a facility's lifecycle.
This new material handling control system has been installed at BHP Billiton's Port Hedland iron ore terminal to facilitate its expansion to beyond 100 Mt output capacity.

KEYWORDS Route, Flow path, Product transport, Automation, Control system, Sequencing, Material handling

INTRODUCTION

In this climate of increasing demand for commodities, it is becoming necessary to expand and optimize the existing bulk material handling facilities in order to increase capacity.

Production capacity in these facilities is often adversely impacted during the expansion process. A successful and proven strategy to reduce this impact is to bring the additional capacity online in stages coinciding with routine maintenance or other short shutdowns. Compatibility of the automation systems with staged upgrades in capacity is key to achieving this successful outcome.

Since 1994, Hatch (Associates) has been researching a generic, highly configurable product transport control system that can be reconfigured to cater for plant expansions or modifications without incurring significant risk to production capacity. During 2001 to 2004, Hatch successfully developed and deployed such a generic configurable control system, known as the Hatch Product Transport (HPT) system, at BHP Billiton Iron Ore's (BHPB IO) Port Hedland ore handling facility.

ROUTE SELECTION AND SEQUENCING SYSTEM

A crucial and integral part of the automation of a bulk material handling facility is the route (flow path) selection and sequencing (RSS) control system. The key functionality of the RSS is to:

- Provide a means for the operator to select a route (flow path) that consists of a series of connected equipment. For example, product may flow from source equipment (e.g. car dumpers, reclaimers), through transport equipment (such as conveyors, feeders), via positioning equipment (e.g. shuttles, gates, splitters), passing quality equipment (e.g. sample station, belt weigher), and finally reaching destination equipment (such as trippers, processing plants, shiploaders, stackers).
- Provide a means of correctly positioning the various positioning equipment to create the desired flow path for material transfer.
- Provide a means of coordinating the starting of equipment in a route in an orderly manner to prevent spillage.
- Provide a means of stopping/tripping upstream transport equipment if downstream transport equipment faults, i.e. interlocking to prevent spillage.

Fig. 1. More than 500 ships are loaded each year at BHP Billiton Iron Ore Port Hedland.

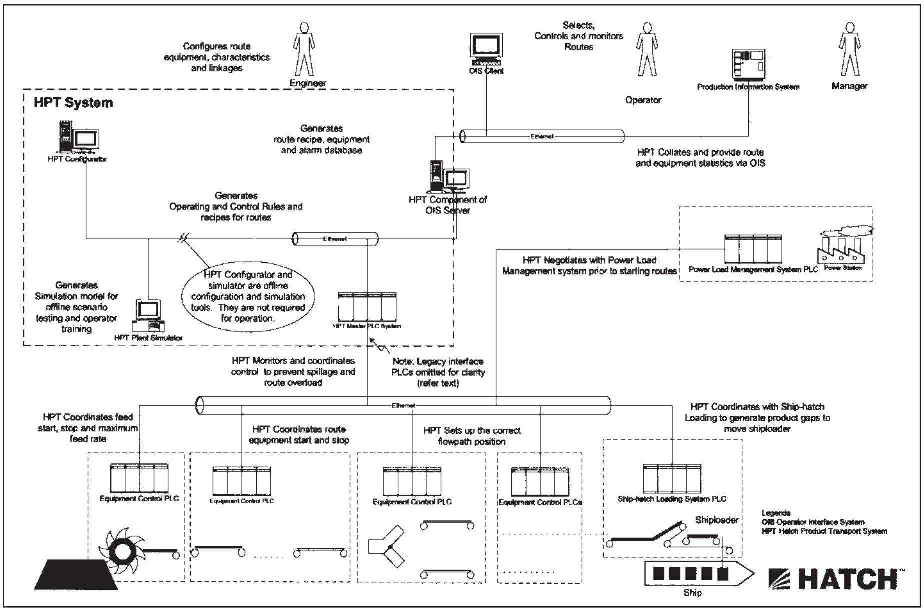

Fig. 2. The HPT system functional block diagram.

- Provide a means of removing an existing route to allow setting up another route, which may share some of the same equipment.

Whenever the facility undergoes an upgrade, the RSS system will need to be modified to reflect any changes to the route combinations. For a conventional (hard-coded, non-generic) system, depending on the size of upgrade, some of these RSS system modifications can be quite significant, taking up to a few months. Furthermore, these modifications can sometimes result in undesirable disruption to production due to the introduction of software errors during the upgrade or unidentified interactions with existing systems.

HATCH PRODUCT TRANSPORT (HPT) SYSTEM

The typical functional responsibilities of the HPT system are (Fig. 2):

1. Equipment control systems—the HPT system:
- sets up the correct flow path by positioning equipment (e.g. position the gates, shuttles along the route);
- coordinates the starting and stopping the route equipment within a route; and
- coordinates starting and stopping, and limits the maximum feed rate of a feed source.
2. Other higher level control systems:
- Power load management system—the HPT system negotiates with this system to ensure that there is sufficient capacity in the power system prior to starting each route.
- Ship-hatch loading control system—the system coordinates the generation of product gaps to allow moving of the shiploader without shutting down the route.
3. Production information system—the HPT system:
- collates and provide route status and statistics (e.g. for a production delay accounting system); and
- collates equipment statistics (e.g. starting, stopping time, stopping distance, etc).
4. Internal route coordination and system function:
- Monitors and coordinates the control of transport equipment to prevent spillage and route overload when a route equipment faults.
- Executes any pre-configured automatic divert strategy to divert from a faulted downstream route segment to an alternate operating route segment, to avoid unnecessary tripping of upstream transport equipment.
- Monitors and prevents route overloading (e.g. adjust the speed reference to any variable speed capable transport equipment to mitigate overloading of a routes).
- Monitors and warns of cross-contamination of products.
- Provides a comprehensive graphical interface for the operator to control, monitor route status, and diagnose problems associated with the operating routes.
- Provides a comprehensive route alarm and event reporting system to facilitate route event reconstruction.

As shown in Figure 2, the HPT system is a supervisory control system that coordinates and controls all route equipment. It controls the equipment via each Equipment Control Programmable Logic Controller (PLC) through a pre-defined sequencing interface. It has a modular architecture (refer to the right-hand corner of Fig. 2) consisting of a central database (HPT Configurator) and a set of systems with generic algorithms. The HPT Master Controller (PLC) and the HPT Operator Interface System (OIS) contain generic control algorithms that act accordingly to the data and rules downloaded from the HPT Configurator. In addition, the HPT system has a plant simulator which facilitates the testing of the HPT system. In order to ensure high availability and robustness of the system, all real-time control functions are implemented in the HPT Master PLC system. The HPT Configurator and Plant Simulator are merely offline configuration and verification tools.

The HPT system has a modular architecture (Fig. 3) consisting of a central database and a set of generic sub-systems that control according to the data and rules downloaded from the central database. The central database, modular architecture, and generic control algorithms allow changes to be configured and comprehensively tested prior to deployment. Using this architecture, the HPT system is able to reduce project risk, deliver future project costs, and schedule savings that are difficult to achieve using a conventional approach (Fig. 5).

The HPT system also has an architecture that facilitates seamless integration of the HPT system with the existing control systems with little interruption to the existing production. Its architecture facilitates progressive integration of equipment. Furthermore, it allows shadowing (i.e. running in parallel with an existing control system in a monitoring mode) to facilitate online pre-validation of the system behaviour prior to cut-over. For example, the HPT system was progressively integrated into the existing BHPB IO control system by using normal day-to-day plant downtime, reducing the major shutdown cut-over time (i.e. time to change over the entire plant with more than 250 items of route equipment) to 8 hours. Since cut-over to the HPT system, the BHPB IO facility has undergone further capacity upgrades with little impact to operations due to route control system modification. Shutdown of the HPT system was not required to implement these control system modifications; other routes unaffected by the changes continued to operate normally during the upgrade.

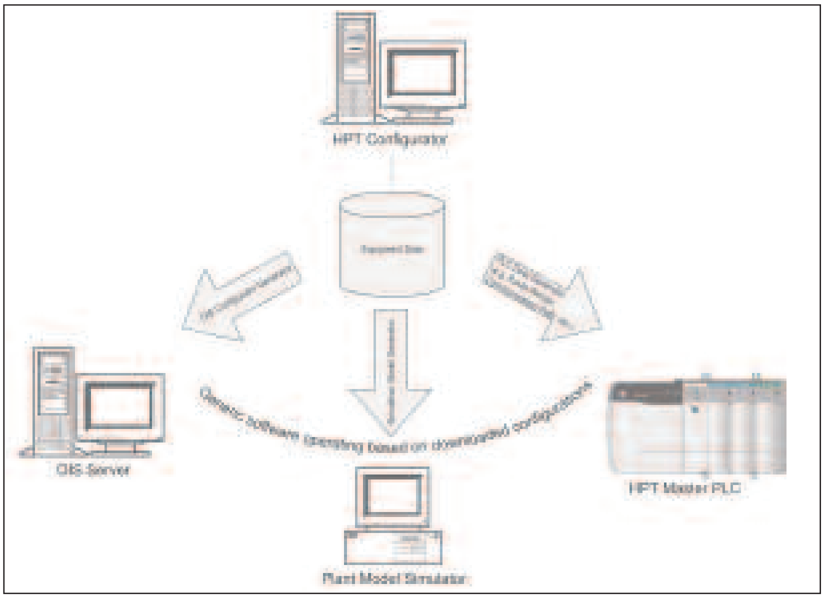

Fig. 3. The HPT system architecture.

LOGISTICS OF BULK MATERIAL TRANSPORT ROUTES

A route (material flow path) is formed by the interconnection of equipment, starting with a defined material source(s) and ending with a defined destination(s), with transporting and positioning equipment in between.

Traditionally, a route is defined as an entity consisting of a combination of sources to a combination of destinations (i.e. each route combination is counted as a separate entity). Figure 4 shows an example of a system with three sources, three destinations, and one common convergent and divergent point. The associated possible route is also shown in Figure 4. The total number of route combinations, based on the traditional route definition for this simple three-sources and three-destination route system, is 49.

The number of route combinations increases rapidly with the number of sources, destinations, and convergent and divergent points in the system.

The HPT system uses a special mechanism[1] to allow representation of all the possible route combinations by using a reduced set of HPT prime routes. For example, the mechanism allows the operation of over 400,000 route combinations at BHPB IO's Port Hedland facility by using less than 250 HPT prime routes.

Note that conventional methodology often required separate hard-coded control algorithms for each route combination. Using the reduced set of HPT prime routes

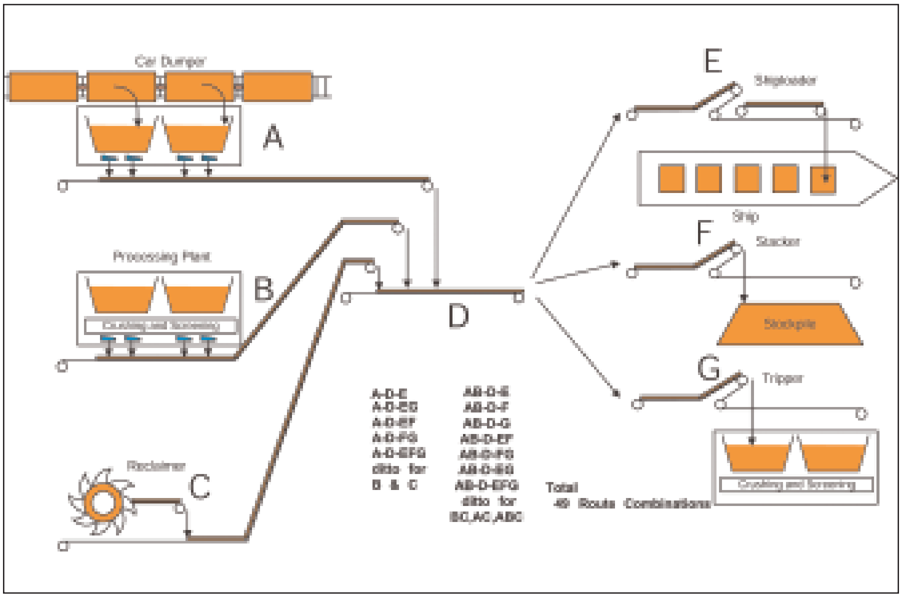

Fig. 4. Example of route combinations from a system with three sources and three destinations.

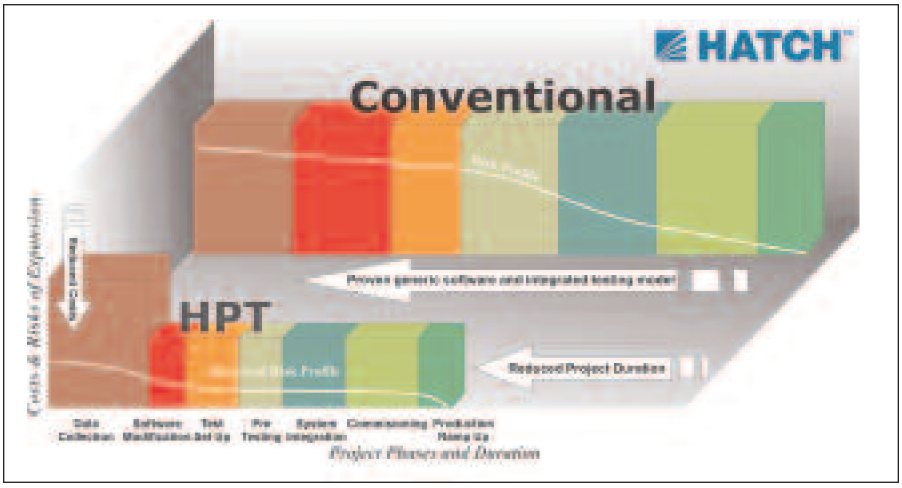

Fig. 5. HPT reduces risks and delivers project cost and schedule savings.

[1] Due to patent application, the actual mechanism cannot be revealed at this stage.

and generic control algorithm, the HPT system allows implementation of all possible route combinations without any additional software modules. This significantly reduces the system complexity and, hence, the risks related to system expansion. Furthermore, it increases the flexibility of the product transport system.

KEY BENEFITS OF THE HPT SYSTEM

The key benefits of the HPT system can be subdivided into two main categories: project and organizational benefits and operational benefits.

PROJECT AND ORGANIZATIONAL BENEFITS

In order to quantify the benefits delivered by using the HPT system with respect to a future upgrade project, Table 1 also compares the conventional approach against a HPT approach. Table 1 demonstrates that the HPT system reduces both the present and future project risks, project duration (hence costs), and facilitates smoother ramp up of production. This is achieved through the use of a central database, generic control algorithms, and an integrated environment that allows all the configuration changes to be comprehensively tested prior to

Table 1. Comparison of the HPT system and conventional system with respect to facility upgrade

Engineering Phases	Conventional		HPT	
	Tasks*	Duration*	Tasks*	Duration*
Data collection	Collate equipment and flow path data.	Dependent on the size of upgrade.	Collate and enter new/modified data into the HPT Configurator database.	Similar
System design:	Identify new or deleted routes and prepare control detailed specification describing the changes to the existing route sequencing and control software.	3-6 weeks – typical not all route combinations are specified.	The HPT Configurator data entry and validation. Use automated tool to identify and generate all possible routes and select the routes to be made available for use.	~1 hour per equipment. For a system with ~200 equipment: 4-6 weeks
Software construction	Coding to handle each route and route combination. Coding to interface with each of the new equipment. Coding for each equipment control. Change values in software for modified equipment. *High risk activity as it may introduce unintended software bugs into the system.*	~1-2 days per route, plus each equipment interface, plus equipment control, plus modified equipment.	Download the selected route changes to the HPT PLC and OIS. Coding to interface with each of the new equipment. Coding for each equipment control. *Low-risk activity as there is no change to the core software.*	1-2 hours to download changed routes/ equipment, plus similar equipment interface, plus identical equipment control system.
Test setup	Code and verify the basic start/stop/ fault simulation model. Model is typically constrained to simulate new routes and equipment and ignore the other/existing routes and equipment.	~1 week (if limit model to new equipment).	Export equipment database to generate comprehensive model for start, starting, running, stop, stopping, stopped states with product flow rates, and faulted event at any state. Validate the model. Model is capable of testing all routes.	1 week (for comprehensive model)
Pre-testing	Test the various scenarios for each of new routes and modified equipment. Regressively test the existing routes having a strong interaction with the new routes. Ignore the existing routes (impractical because of the time required to test each combination of routes).	~1 week (if limit model to new equipment); plus ~5 weeks for strongly dependent routes; other route testing impractical.	Since changes have been made solely to data and not the core software, near full coverage is provided by testing routes corresponding to new or modified equipment. The level confidence can be further increased by testing the specific existing routes (optional).	~1 week for all new or modified routes, plus ~1 week for strongly dependent routes, plus ~1 week for specific routes (optional)
System integration with production system	Recoding the offline pre-tested software as online changes to the production system (typical). *High risk of causing production disruption as a consequence of (a) re-coding error; (b) changes in compatible with interim changes to the production system; and, (c) unidentified impact upon the existing route operation.*	2-5 days (excluding equipment control system)	No changes to production software. *Route system changes are restricted to data. Data downloaded to the production systems is identical to the data tested – hence very low risk of disrupting production.*	1-2 hours (excluding equipment control system)
Commissioning	(1) New routes and routes with modified equipment are tested and verified. (2) Commissioning team retained on standby to quickly attend to unforeseen impact upon operation of the existing routes.	(1) Dependent on the number of new routes and routes with modified equipment; plus (2) dependent upon the total number of routes.	New routes and routes with modified equipment are tested and verified. No need to verify other routes. No need for route system commissioning team to be on standby. *The confidence level is much higher (hence lower risk) due to no changes being made to the core software.*	(1) Similar for new routes and routes with modified equipment portion. (2) Nil.
Production ramp up	Production ramp-up often extended by untested transient events and other effects upon the existing routes.	Dependent upon the total number of routes.	Production ramp up is likely to be smoother as a consequence of no changes to the core software and superior test coverage.	Shorter than conventional.

***** Typical tasks and respective estimated duration for a system with a few hundred items of route equipment and a few hundred non-branching flow paths.

deployment. These benefits are difficult to achieve using a conventional system.

Furthermore, the HPT system provides a platform that facilitates continuous plant improvement and reduces the overall life cycle costs associated with the automation of route systems. Figure 5 summarizes these benefits graphically for a typical project life cycle.

Table 2 demonstrates the organizational benefits of the HPT system for a new route control system and the modification of an existing route control system. The much shorter project duration and reduced risks facilitates the attainment of plant production objectives, which are crucial in ensuring the ability to both meet the increasing demand and in capturing new markets.

OPERATIONAL BENEFITS

Besides the project-related benefits, the HPT system also has a number of advanced and innovative process control functionalities which improves the overall productivity of the plant. Table 3 demonstrates the operational benefits of the HPT system compared to a conventional route system. Using the material interlocking concept, the HPT system utilizes the latent plant availability to improve performance and productivity.

Furthermore, the modular system architecture and the special HPT route definition and operational concept of the HPT system:

- simplifies the selection and operation of routes;
- improves production efficiency by reducing the route startup time, change-over time, and material delivering time;
- reduces risks to production during transport route upgrade or expansion;
- facilitates continuous improvement by enabling availability of integrated plant operational data (such as route, equipment, and production data) for performance analysis;
- improves maintainability of the plant by having a single configurable repository of data complemented by generic control algorithms, and also ensures system integrity by providing traceability for any changes to the configured data;
- improves plant availability by reducing the downtime required for plant modification; and
- facilitates determination of the optimum operational strategy and ensures smooth startup—the HPT system has an integrated plant simulator to provide a platform for both operator training and trialling various operational scenarios.

CONCLUDING REMARKS

Hatch installed a HPT system at BHPB IO's Port Hedland facility in April 2004. The system has been in operation for more than two years, and was cut over in significantly less time than originally estimated. Since

Table 2. Organizational benefits of the HPT system

Activity	Conventional	HPT	HPT Benefits
New route control system realization	System design: 2-4 weeks Due to costs, typically not all the possible route combinations are implemented.	System design: 4-6 weeks (mainly associated with the HPT Configurator data entry and validation). All possible route combinations are available for operation.	System delivery saving of: >40 weeks
	Software (sequencing portion) e.g. construction for a system with a few hundred routes: 40-50 weeks (depends on complexity of the flow paths).	Software (sequencing portion) e.g. construction for a system with a few hundred routes: 0 weeks.	
	Testing: Due to costs of setting up the simulation model, the tests often only provide partial route/ sequencing system coverage.	Testing: Due to ease of generating the simulation model, it is possible to provide near full route/ sequencing system coverage.	Lower project risk since near full system testing coverage. Time saving is not compared as it is dependent on the scope of the testing.
	Production ramp-up susceptible to delay as a consequence of partial testing .	Production ramp-up most likely to proceed as planned due to near full test coverage	Less risk to production ramp-up schedule since no changes to core sequencing software and near full test coverage.
Route control system modification	System design: 1-3 weeks Software (sequencing portion) Construction for say 20 routes: 3-6 weeks.	System design: 0.2 weeks (mainly associated with the HPT Configurator data entry and validation). Software (sequencing portion) construction for say 20 routes: 0 weeks.	System delivery saving of 4 to 9 weeks
	Testing: Partial route/ sequencing system coverage.	Testing: Near full route/sequencing system coverage.	Lower project risk since near full system testing coverage.
	Production ramp-up susceptible to delay as a consequence of unforeseen, non-tested deleterious effect of changes upon the existing route operation.	Production ramp-up most likely to proceed as planned due to near full test coverage.	Less risk to production ramp-up schedule since no changes to core sequencing software and near full test coverage.
Provision of information for higher level systems	Typically equipment status, starting, stopping times.	Route identification and status, product types, feed rate set points, route equipment membership, equipment status and statistics such as starting, stopping time for each equipment.	Permits route and equipment analysis by higher level systems e.g. delay accounting system.

Note: Activities of similar duration are omitted from the process of benefit comparison.

Table 3. Operational benefits of the HPT system

Activity	Conventional	HPT	HPT Benefits
Starting of routes	Route is always started in sequence from downstream to upstream. The system starts an item of upstream equipment when the immediate downstream equipment has reached a particular speed threshold.	The HPT system can start route equipment without burden simultaneously. In this situation the starting time for the route is equal to the equipment with the longest starting time.	Each start of an empty route may provide an additional production time of ~4 minutes/event.
	Basis: route of 10 items, 3x1min start-time, 3x1.5min, 2x3min, 2x7min @ 40% threshold = 0.4x(3+4.5+6+14) = 11 minutes	The HPT system starts an item of upstream equipment with burden when the immediate downstream equipment has reached a particular speed threshold.	Basis: The starting time for the HPT system is equal to the equipment with the longest starting time (say 7 minutes), hence (11-7) = 4 minutes saved.
Route equipment faulting	As soon as any downstream equipment faults, production stops, and all upstream transport equipment is stopped. Production loss is the fault repair time plus the route segment upstream of the fault start time.	The HPT system has a production centric control philosophy: • Produce unless spillage is likely to occur; • Assess each item of equipment and stop immediate upstream equipment if spillage is imminent otherwise let it continue to run; and • Upon downstream fault and if there is a positioning device upstream capable of online movement and configured to do so, the HPT system will automatically divert the ore stream away from the faulty segment to prevent unnecessary tripping of upstream equipment.	Additional production time of ~1 to 7 minutes/event. Basis: Time saving is dependent on the burden free transport time to the faulted equipment and sometimes the starting time for the route segment that would otherwise have stopped. Note: (a) the starting time for the route segment with burden that is stopped is similar for both systems; (b) occasionally the equipment re-starts before the burden reaches it. In this case, the production increase includes the re-start time for the otherwise stopped segment. Hence if burden free segment: eg. a 4m/s transport system and length of ~400 m, approx 1.5 minutes; and if avoid stopping/re-starting then. (11/2)=~5.5 minutes giving ~7 minutes saved.
Preloading of upstream segment of a route	Many conventional systems have a conservative interlocking philosophy and will not allow preloading of any upstream segment of the route while downstream is stopped or unavailable.	The HPT system uses a material interlocking philosophy, hence it allows the upstream segment of the route to be preloaded while the downstream equipment is stopped or unavailable.	Additional production time of ~1 minute/event. Basis: The time saving is dependent on the length segment which can be preloaded e.g. for a 4m/s transport system and length of ~400m, approx 1.5 minutes.
Swapping routes with common equipment	Even though two routes may share some common equipment, in order to change from one route to the other, the first may need to be stopped before the operator can set up the second route and start it.	The HPT system simplifies combined route operation. This allows the second route to be set up and started before the first route is stopped without the need to stop any of the common equipment.	Additional production time of ~13 minutes/event. Basis: Using the HPT combined route operation a running route saves the equivalent start time of an empty route plus the stopping time of the existing route, eg. conventional starting time of 11 minutes plus stopping time ~2 minutes = 13 minutes saved.

the handover, the HPT system has met the demanding performance conditions of the original specification, including facilitating five further expansion upgrades to the facility. It has helped to reduce the required interruptions to the operation during these expansions.

Work is currently underway to further enhance the system functionalities such as providing an integrated production tracking system. Hatch intends to further enhance the system by adding production schedulling, and planning optimization modules to the system in the near future.

In summary, the Hatch Product Transport (HPT) System is a generic route selection and sequencing system which facilitates continuous expansion of a bulk materials handling facility, delivering reduced project risk, and costs and schedule reductions as shown in Figure 5.

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BIBLIOGRAPHY

BHP BILLITON, 2004. BHP Billiton Completes Iron Ore Products and Capacity. Available at: http://www.bhpbilliton.com/bb/investorsAndMedia/newsAtBhpBillitonDetail.jsp?id=News%2F2004%2FNews%40BHPBilliton160204.html

STANDARD IEC 61131. Programmable Controllers, International Electrotechnical Commission (IEC).